Installation, commissioning and maintenance guidelines

for electrohydraulic systems

1 PREPARATION AND START-UP

A proper assembly and a right installation are determinant factors for a good operation of an hydraulic system in the time.
The reliability of any machine or hydraulic system is depending upon quality and state of the power transmission fluid and upon the cleanliness of the circuit from impurities. It has to be remembered that the same fluid provides the lubrication of the circuit components.
Therefore it is very important to provide the following conditions:

- **during the project:** continuous filters for oil, sized according to the class, the type of installation and the performance required.
- **during the assembly:** it is necessary that the main connections are made in a clean and not dusty room: remove any scale which could get into the circuit. The pumps and all hydraulic components are always supplied with plugged ports; these plugs have to be removed only at the moment of the installation. When the component is installed, as a good rule, fill some hydraulic oil to protect the internal parts until the hydraulic circuit will be filled for operating. Provide picking of the pipings and the circuit flushing.
- **during the operation:** check accurately the filters with frequent cleaning or replacing of the cartridges.

The following notes give some general suggestions and directions for the installation, commissioning and maintenance of main components.

1.1 Piping and fittings

In the hydraulic installations cold-drawn seamless pipes conforming to the international standards have to be used. The fittings have to be selected considering the installation characteristics, the operation pressure and the pipe diameters.
Use as rule:

- up to nominal size DN 40, pipe unions with grip ring (for average duty installations and without vibration).
- up to nominal size DN 40, pipe unions with welded stub and taper seal with O-ring (in heavy duty installations).
- bigger sizes than nominal size DN 40, flange connections.

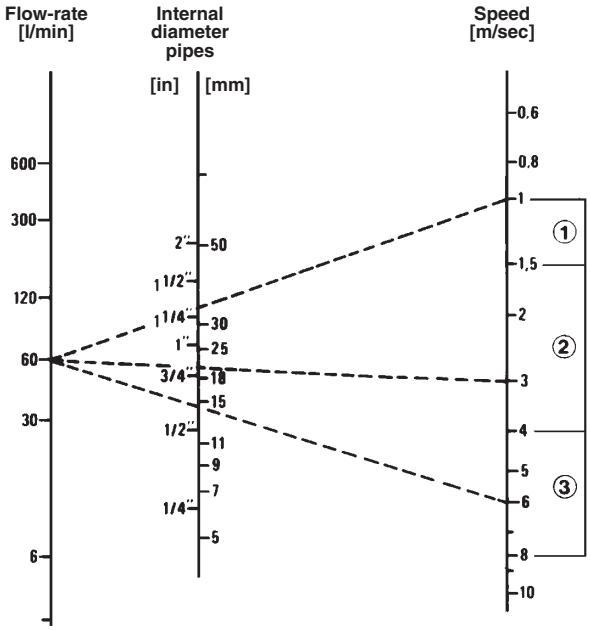
The pipe diameter has to be taken considering the maximum oil flow in each section of the circuit: this flow can be remarkably higher than the pump delivery; however don't exceed the following speed limits (see fig.1):

- 1 → 1,5 m/sec in intake pipes
- 1,5 → 4 m/sec in return pipes
- 4 → 8 m/sec in pressurized delivery pipes.

Use the lower speed values for low pressure installations and/or with continuous operation.
A safe sizing of the intake pipes and of the return pipes to the reservoir is very important.
The intake pipe shall be as short and direct as possible: avoid sudden elbows, reduction of sections and throttling which could spoil the good operation of the pumps.
The pipings have to be pickled, neutralized and then washed with oil. The pickling is necessary to eliminate rust, scale and welding borax, etc.
Add phosphating treatment of the pipings, if necessary. However the piping have to be perfectly clean.
During the installation, the pipings have to be duly mounted with a sufficient number of fasteners; for this purpose, plastic clamps are used normally in polyamides or in polypropylene.
It is recommended to determine the number of fasteners required following these average distances: 1500 mm for pressure pipes and 3000 mm for low pressure pipes (return and drain lines).
When connecting hydraulic components ensure that pipings and the components themselves can be easily disconnected and replaced when necessary.
When installing flexible pipes, avoid too narrow radii and torsional stress (see figure 2); the flexible pipes have to be sized for a pressure value twice that of the maximum operation pressure, to account for the sudden pressure peaks. The drain connections of hydraulic motors and of the hydraulic valves must be duly connected to the reservoir separately from T connection, if some counter pressure on it were foreseen.

Figure 1 Graph used for calculation of the oil speed in the pipes

Recommended speed:
① intake pipes
② return pipes
③ pressure pipes

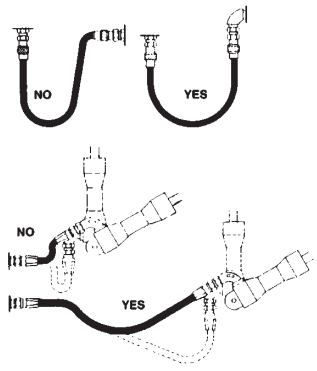


Example: with flow rate of 60 l/min and flow speed of 1,3 and 6 m/sec the recommeded internal diameter of the pipe is 33,20 and 14 mm respectively.

1.2 Oil reservoir

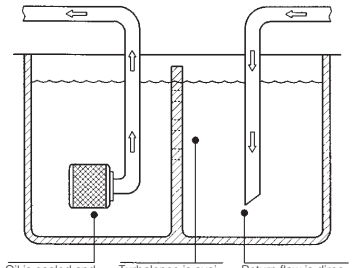
The oil reservoir has to be sized in conformance to: installed electric power - pump delivery - heat quantity generated during the operation - type of installation and duty.
As a general rule, it is suggested to provide an oil capacity equal to 2 → 4 times the pump delivery per minute (according to the operation pressure and the duty). For example , if a pump has a delivery of 25 l/min, it is recommended to take a reservoir having a capacity of 50 to 100 liters. This rule is suggested on considerations about heat losses; in particular cases, where it is required to limit the reservoir dimensions, properly provide in the circuit a cooling equipment.

Figure 2 Installation of flexible pipes



The use of cooling apparatuses is necessary in those circuits where a remarkable amount of heat arises and always in the installations with continuous operation and high installed power. Remember that the oil temperature in the reservoirs shouldn't exceed the prudential limit of 50°C (maximum 60°C) where the optimum operation is considered in the range 40 to 50°C.
Of course, the reservoir capacity shall consider also the oil quantity which can be stored in the circuit during particular phases of the operation.
In small plants the pumps are commonly located above or inside the oil reservoir. In the installations with big pump delivery or equipped with piston pumps for high pressure, it is necessary that the reservoirs are set at an higher level than the pumps in order to have the intake under some head.
The reservoirs have to be accurately cleaned and painted inside with a paint resistant to the hot oil. The reservoir must be sealproof except for the air port to allow the air movement (during the oil level changes); this port has to be duly protected against dust and impurities through an air filter.
The oil return pipes form the circuit have to be extended inside the reservoir with the end under the minimum oil level to avoid foaming. Ensure that the return flow to the reservoir doesn't affect the pump intake.

Figure 3 Intake/return lines inside reservoir



In the reservoirs having a big capacity, commonly internal baffles are provided for the separation of the oil return area form the pumps intake, in order to brake the swirling movement of the liquid and to allow the setting of solid suspended particles and also of the water, if any.
It is important that the reservoir is built in such a way as to be easily accessible for a periodical cleaning.
Provide on the reservoir bottom a drain in correct position for the draining of water deposits and the emptying for maintenance purposes.
To make emptying easier, it is required that the reservoir bottom is higher than the floor level, and possibly sloping towards the drain hole.
The oil reservoir must always allow to check the oil level and shall be equipped with the indications of the maximum and minimum level required.
The maximum level shall account for possible oil outlet and the minimum level must prevent air inlet through the pumps intake port.

1.3 The filtering function

Among the main causes of fault and stop of an hydraulic installation, the most usual is the block of components due to seizing or breakdown wear and ageing of the power transmission fluid with consequent loss of its operation properties.
Particles and microparticles which circulate continuously in the fluid constitute a cause of wear: if these micro-particles circulate freely in the system, they act as an abrasive mix wearing the contact surfaces and taking into circulation more contaminant; damage will be bigger the more sophisticated are the components.
The filter, or in general the filtering function must eliminate these particles and micro-particles to ensure maximum efficiency and lasting time of the hydraulic system.
The choice of the characteristics and number of filters is made according to the type of plant and of the components which have to be protected: .

- for standard industrial plants a filtration rating of 25 µm is required.
- for circuit equipped with proportional valves, a filtration rating of at least 10 µm is necessary.

About their location in the circuit, consider the following possibilities:

- location on the intake;
- location on the return;
- location in line.

It is particularly recommended that the filter be easily accessible for a periodical cleaning; this cleaning must be made weekly; provide filters having visual or electric clogging indicators to ensure easy control.

1.4 Pumps and motors

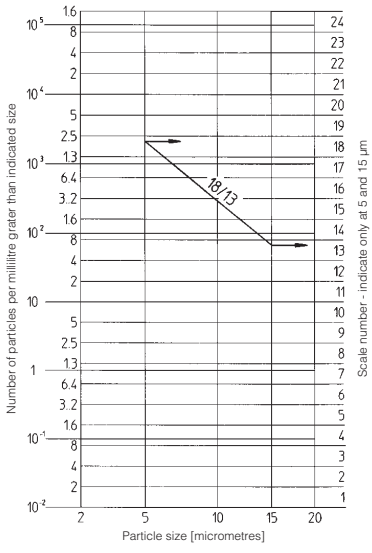
The various types of hydraulic motors and pumps may require special standard of installation which are specified by the manufacturer's directions.
However, some general rules apply to the most cases.
The connection to the driving motor should be made preferably with an elastic coupling. If a different type of transmission is required, consult the manufacturer: only a few pumps allow radial or axial load.
Comply with the rotation sense of the pump which is always shown by an arrow on the pump body.
Never strip the pump: the modification of the sense of rotation or of the ports position (if possible) must be made by the manufacturer (except when it is expressly allowed).
The intake conditions of all pumps are a very important item; therefore make the oil flow the easiest possible, purposely use widely sized pipes.
Some type of pumps and motors have specific ports on the body to drain the internal oil leak; these ports have to be connected to the reservoir.

2 HYDRAULIC OIL RECOMMENDATIONS

2.1 General data

In hydraulic circuits the oil is the power transmission medium and at the same time the components lubricator; for a long life of the plant the oil to be of good quality with an high viscosity index and with anti-frothing and anti-oxidizing agents conforming to the international standards (DIN 51524 and 51535).
In particular the use of mineral oils belonging to group H-LP according to DIN 51524 part 2 is recommended.
The oil viscosity has to be chosen suitable to the type of hydraulic pumps and motors installed, further to the temperature of operation of the circuit. First of all check the directions supplied by the manufacturer about pumps and motors.
The selection of a hydraulic oil of a specific viscosity range must be based on the needs of the system, limitation of possible critical components, or proper performance of specific type of units. Very high viscosities at start-up temperatures can cause noise and cavitational damage to pumps. Continuous operation high viscosities will tend to hold air in suspension in the oil which can cause noise and early failure of pumps, motors and erosion of valves. Lower viscosities result in decreased system efficiency and impairment of dynamic lubrication.
In fig. 5 are shown the average curves viscosity versus temperature for the most commonly used oils, subdivided in three groups each one with a different viscosity; the table 6 shows the codes corresponding to different oil manufacturers.
The oil mostly used is that corresponding to curve "B" having viscosity of 24 → 28 cSt at 50°C.
But also less viscous oil (6 → 11 cSt at 50°C) or more viscous ones (up to 58 → 72 cSt at 50°C) can be used; keep always in mind that less viscous oils have to be employed for lower pressure (to limit the pressure drop) and more viscous ones for higher pressure (to limit internal leakage). It has to be kept in mind that a too viscous oil can bring some difficulty in the start at ambient temperature, because the most hydralic pumps do not operate properly at normal speed viscosity higher than 290 → 365 cSt.
In particular conditions, different types of oil have to be adopted, e.g. there are oil suitable for employment outside at a very low temperature, particularly in those cases where no gradual starting is allowed, but the system has to be ready for operation whenever needed (e.g. in ropeway installations); further in those cases where a fire resistant oil is required and so on.
The temperature of operation shall be kept as a rule in the range 40 to 50°C, avoid to exceed 60°C, because beyond this limit the seals begin to wear.
Consider that a new mineral oil, as it is supplied by the manufacturing companies, contains a certain number of contaminant particles; this contamination arises from the handling during shipment and packing.

Figure 4 Fluid contamination level according to ISO 4406



Example:
the indicated 18/13 oil contamination code corresponds to about 2200 particles greater than 5 µm and about 80 particles greater than 15 µm each millilitre of oil

Before putting the fluid into the circuit, the user must clean it accurately; it is recommended to fill the reservoir using mobile filtration units.

The oil change must be made as a rule every 2000 hours, It is recommended, however, to analyze oil samples to check its chemical-physical properties, since the lasting time indicated above is approximate and depending upon the plant characteristics and operation, as on climatic conditions and accuracy of filtration and maintenance.
Topping up of the reservoir must be made with an oil of the same mark to avoid functional faults of different kind.

2.2 Fire resistant fluids

The mineral oils have a quite low ignition and self-combustion temperature; moreover when they ignite, the combustion spreads and the danger becomes bigger.
Therefore, when fluid leakage can increase fire risk, special products are used which have a bigger resistance to fire.
Most diffused fire resistant fluids are phosphate ester fluids and water-glycol solution.

The phosphate ester fluids show these characteristics:
high resistance to combustion with poor flame propagation, good lubricating quality, quite good rust inhibit characteristics, limited viscosity index, high specific weight, non-compatibility with rubber and paints. Disadvantages are: toxicity and pollution class.
Therefore when these fluids are used, the hydraulic installations shall comply with particular directions:

- use of seals and flexible pipings in suitable elastomers (mainly Viton or P.T.F.E.);
- no use of paints inside the reservoir and on surfaces which can get in touch with the fluid (except in very particular cases and when qualified technicians have been consulted);
- very accurate continuous filtration of the circuit owing higher fluid density.

The phosphate ester fluids allow high operation temperatures (even higher 100°C); they have an optimum resistance to ageing and do not require special maintenance except a periodical check of the water content; it makes this fluid to a wearing agent still in little percentage.

The water-glycol fluids are compound mixes with water 40 → 50% and ethylene or propylene glycol and polyethylene glycols. The combustion resistance derives from the water content: periodically, a check of the mix compound is necessary in order to top it up with water; these mexes have the disadvantage to alter the characteristics quite easily for evaporation.
Water-glycol main characteristics: high visco-

sity index, fairly good lubricating property; good rust inhibiting quality, non-compatibility with paints and high density.
When these fluids are used, it is recommended to:

- check the compatibility with the seals; this condition is normally sure almost for the static seals in the valves.
- do not paint the reservoir inside; no cadmium coated components are allowed.
- design bigger reservoirs (with contents equal to 8 → 10 times the pump delivery).
- provide an efficient temperature control of the fluid; keep it in the range 40→50°C; never exceed 60°C.
- size the plant for limited flow speed (max 3 m/sec).
- reduce pump speed; don't exceed 1500 rpm (the use of gear pump is not allowed).
- reduce the maximum operation pressure: don't exceed 100 → 120 bar.

Different fire resistant fluids are also available, see ISO 7745 standards.

3 FLUSHING OF THE CIRCUIT

In new plants, although it has been complied with the above described prescriptions, it is impossible to eliminate completely the contaminants. Therefore for a new plant it is necessary to undergo a flushing operation beforehand.
To avoid that the contaminated oil will damage the circuit components proceed as follows:

- shunt the users, motors and cylinders, and also the control valve boards;
- open fully throttling valves installed in line;
- separate the accumulators from the other parts of the circuit;
- provide on the return piping two series installed filter batteries having filtration rating 125μ and 25μ (10μ) respectively, in order to get a better filtration than in operation.

The circuit flushing, according to the indications given above, can be performed with the same power unit. For big sized or important plants, a proper flushing assembly with own pump and reservoir has to be used.
The flushing fluid has to be chosen among good quality mineral oils, in conformance with the directions of a qualified oil manufacturer and must be compatible with the seals and the operation fluid since flushing fluid can be removed completely from the circuit.
The recommended flushing speed is 5-6 m/s. Flushing has to be performed with warm oil (about 40°C).
The time necessary to this purpose cannot be stated in advance, however it shall not be less than 40 - 50 continuous hours.

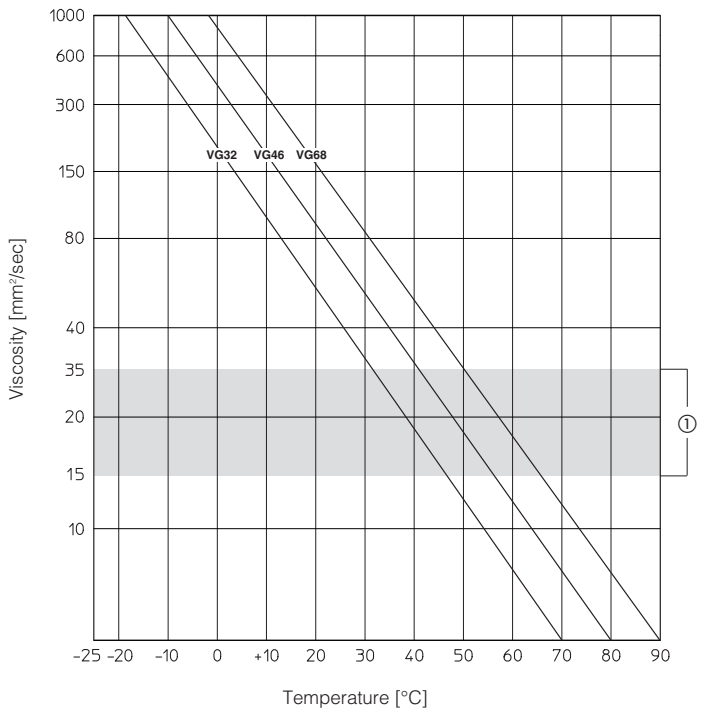
4 PLANT COMMISSIONING

When starting the pump units, follow these directions which are necessary to ensure at once the needed lubrication to the internal parts:

- ensure that gate valves both on the intake and on the delivery side are open;
- fill the pump body with the circuit fluid through the drain port or, if not possible, through the delivery pipe;
- set the pressure relief valve in venting position on the delivery pipe. The pumps shall be started idle, as a rule. For other directions consults the manufacturer;
- pulse start the electric motor to make the pumps priming easy; it will be indicated by a pressure gauge on the delivery and by the change of the pump noise, which will become quieter after priming.

During the circuit topping-up provide air bleed; air inside causes operation troubles and fast wear. To make this operation easy, on the delivery side of the pumps air bleed valves can be installed. The air in the pipings can be blad off loosening the fittings located in the higher parts of the circuit providing valves for cylinders.
The air bleed off is shown by foam: when the oil flow comes out continuous and clear, the air is out. After the filling and the air bleed have been performed, check the oil level in the reservoir and top it up, if necessary; then pressurize progressively the circuit and go on calibrating and setting the regulation valves.This phase should be performed at operation temperature.
Ensure that no foam is built in the reservoir; it would show air in the pump intake.

Figure 5 Viscosity Vs. Temperature graph



① Optimal range for continuous operation

DIN 51524/part 2 June 1979	H-LP 32	H-LP 46	H-LP 68
ISO VG ref	32	46	68
AGIP	OSO 32 Arnica 32	OSO 46 Arnica 46	OSO 68 Arnica 68
IP	Hydrus 32	Hydrus 46	Hydrus 68
BP	Energol HLP 32	Energol HLP 46	Energol HLP 68
CASTROL	Hyspin AWS 32	Hyspin AWS 46	Hyspin AWS 68
ESSO	Nuto H 32	Nuto H 46	Nuto H 68
MOBIL	DTE 24	DTE 25	DTE 26
SHELL	Tellus 32	Tellus 46	Tellus 68
CHEVRON	EP Hydraulic Oil 32	EP Hydraulic Oil 46	EP Hydraulic Oil 68
TOTAL	Azolla ZS 32	Azolla ZS 46	Azolla ZS 68
Figure 5 correspondence	VG32	VG46	VG68

5 MAINTENANCE

An hydraulic system, well installed and fitted during mounting and commissioning, ensures a long life without faults and doesn't need any particular maintenance care.
The basic principle for a good management, is the absolute need to check continuously the quality and the state of the power transmitting fluid and the contaminant-free state of the circuit; upon it depends the reliability of every hydraulic machine.
The plant maintenance is composed by many small operations which need to be performed at regular time if they must be effective. Therefore it is very important that these control and check operations, although simple, be planned and enlisted on machine or plant cards, which are component part of the plant itself. On these cards the maintenance staff shall record the service made and the troubles which have been found.

The following periodical operations are recommended:

5.1 External cleaning, monthly. In this way the leaks can be found easily and one can get immediately to the trouble.

5.2 Check of air filters, monthly; replace the cartridge, if necessary. The checking period can be changed according to the direct experience and the ambient conditions.

5.3 Check of oil filters. As it has been already stated, this operation is of maximum importance. It shall be made weekly at least.
In the most important plants, filters with clogging indicators and electric monitoring can be used; in this way the signal of fault can be indicated in the control room so avoiding the possibility of forgetting service; an automatic

sequence for the circuit block can be provided.

5.4 Oil topping-up. It has to be made whenever the level is minimum.
The maintenance is easier by installing electric indicators of minimum level and pumps stop sequence.
The oil topping-up has to be made with the same oil used for the first plant filling; the type has to be indicated on the unit reservoir.

5.5 Continuous control of the oil temperature. The deterioration of the fluid with the temperature is a cause of degrading of the plant. The build-up of degradation products from the hydrocarbons is influenced in a big manner by heat. Up to 60°C the oxidation speed can be taken as constant; from this point on, every 10°C increase double this speed.

5.6 Oil change: every 2000-3000 hours in the average; frequent check of the chemical-physical properties and of the contamination rate allows service in due time. When the oil is changed, perform also an accurate cleaning of the reservoir, and also a flushing of the whole plant, if necessary.

5.7 Heat exchanger: must be cleaned approximately every 6 months; the service time can be changed according to the type of water used and to the direct operation experience. More frequent control has to be made on the water filter. The daily check of the oil temperature shall indicate the progressive worsening of the heat exchange conditions and the need of service.

5.8 Check the pressure preload of the accumulators, monthly; use the right checking and loading instruments.

5.9 Pumps, solenoid valves and regulation components must be treated separately. It is possible to plan a series of check-ups at predetermined time which can help in order to state if the service is needed. In the most important systems motor-pump units as spare have to be provided in order to make possible to check the pump delivery with the system in operation or to check the leakage, if any: both data are indicative about the efficiency, then of wear state.
The same thing applies to the solenoid valves: a check-up of the leakage performed, e.g. every 6 month on the test stand can help to decide if the component has to be replaced.
It is necessary that the plant since commissioning be equipped with a first aid spare parts; it must be always complete and the sufficient quantity of each component should be available.
Here as follows we give a table which can be a useful guide for the troubleshooting.

Table 7 GUIDE FOR THE MAINTENANCE OF HYDRAULIC SYSTEMS

TROUBLE	LIKELY CAUSE	HYPOTHESIS OF SERVICE
PRESSURE TOO LOW or pressure below the correct circuit value	1) pressure relief valve half-open	a) setting pressure too low b) wear of sealing seats c) contaminant matter under seats d) spring broken
	2) pump faulty	see point 5 to 11
	3) excessive internal leak	a) worn seals in cylinders or in hydraulic motors b) wear of valves and distributors c) too low oil viscosity
	4) excessive pressure drop	a) too high oil viscosity b) poor sizing of oil paths c) oil paths partially stopped
PUMP FAULTY for zero or poor delivery compared to standard values	5) intake throttled	a) intake filter too little or clogged b) intake pipe stopped c) intake pipe too small or wound
	6) air inlet	a) at intake port in the reservoi b) in intake fittings c) at the seal on the pump shaft d) for intake of oil with foam
	7) reservoir sealproof	air bleed in the reservoir clogged
	8) drive faulty	a) check the coupling b) too high or too low speed
	9) too high oil viscosity	see pump prescriptions
	10) fault inside the pump	a) internal seals broken b) seized vanes, cheekplates or pistons c) pump head not tightened d) broken internal parts to replace
	11) pump worn out	pump to be replaced
PUMP NOISY unusually (e.g. some gear pumps are always quite noisy)	12) cavitation	a) intake throttled: see point 5 b) high viscosity: see point 9
	13) air inlet	see point 6
	14) internal wear	too high backlash in the supports and cheekplates
OVERHEATING that is, the oil temperature rises above the prudential limit of 50/60°C	15) maximum pressure too high	valve setting too high
	16) useless engaged power	a) cutoff valve operation faulty b) shuting at cycle end not operating c) hydraulic circuit to be modified
	17) excessive internal leak	see point 3
	18) excessive pressure drop	see point 4
	19) oil capacity not enough	make oil capacity bigger
	20) cooling not enough	a) add more cooling b) cooling media not efficient
	21) excessive friction	a) faulty internal assembly of the pump b) lack of lubricating where required c) poorly lubricating oil
WRONG MOVEMENTS of the parts moved hydraulically than stated in the cycle	22) air in the circuit	a) vent air bubbles in higher located parts b) eliminate air inlet see point 6
	23) valves blocked	a) valves blocked at closing by rubbers or other matter b) valves half-open due to contaminant matter
	24) cylinders blocked	a) cylinders internal assembly faulty b) loads perpendicular to the axis not allowed c) seizing of connecting pivots
	25) pressure drops too high	see point 4
	26) variable pressure in the accumulators	a) accumulators capacity poor b) higher request by the circuit owing to internal leakage
EXCESSIVE WEAR that is, too fast compared with the actual operation time	27) oil containing wear agents	a) oil too old b) filters not efficient
	28) poor lubrication	a) oil of poor quality b) oil too fluid at the operation temperature
	29) high operation pressure	compared to the maximum permissilble pressure for pumps and valves
	30) faulty couplings	unnormal loads on shafts or on rods