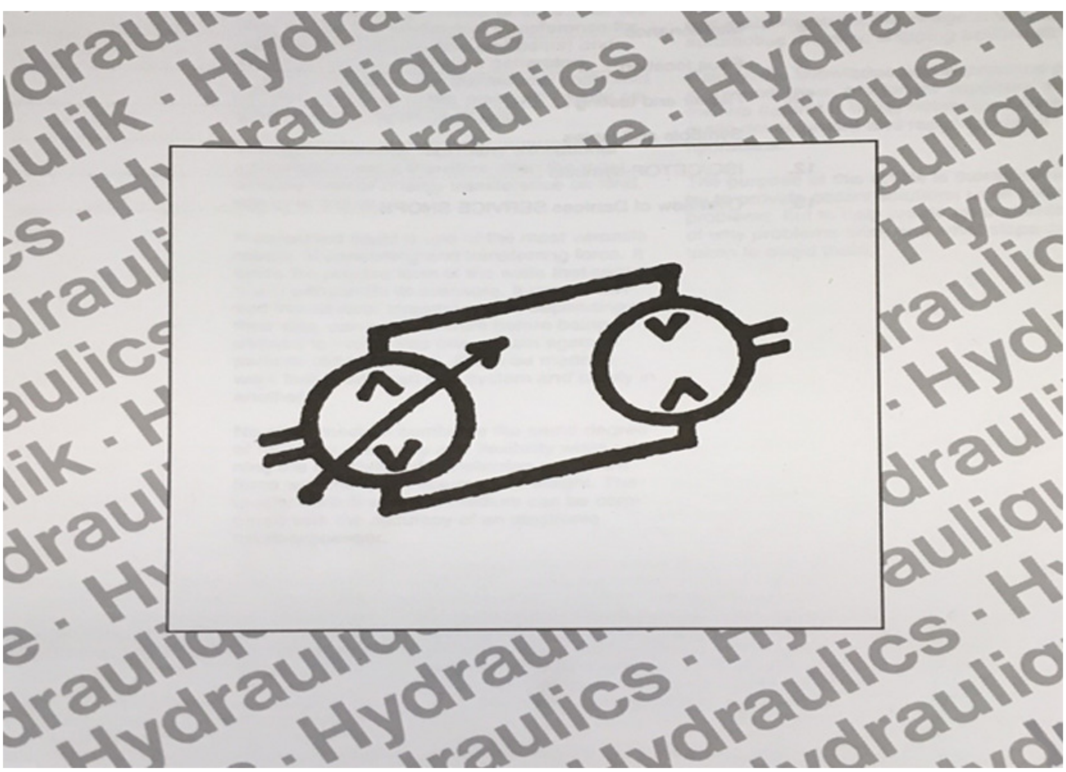
ENGINEERING TOMORROW

Technical Information

Tips on Hydraulics



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Revision history

Table of revisions

Date	Changed	Rev
October 2019	1994 version scanned, then recreated	0101

Contents

Contents

Introduction

Like so many other technical fields, hydraulics is both old and new at the same time.

Take waterwheels for example, people have been using them since before history was recorded. On the other hand, the use of liquid under pressure to transfer force and also to control complicated movements is relatively new and has undergone its most rapid development within the last 40-50 years, not least because of the work that has been done in aeronautics.

Hydraulics and pneumatics are universal for the entire engineering industry and are amongst the three most important media for the transference and control of force. The two other media are mechanical transference for example via clutch pedals and gears) and electrical (for example via a generator). "Flowing energy" is transferred and controlled through a medium under pressure - either air (pneumatic) or liquid (hydraulic).

This form of energy has many exceptional advantages and is therefore often the most suitable form of energy transference on land, sea or in the air.

A contained liquid is one of the most versatile means of controlling and transferring force. It takes the precise form of the walls that contain it and withstands its pressure. It can be divided into several streams which, depending on their size, can perform work before being allowed to merge into one stream again to perform still more work. It can be made to work fast in one part of a system and slowly in another.

No other medium combines the same degree of reliability, accuracy and flexibility while retaining the capability of transferring maximum force with minimum volume and weight. The quality control with this medium can be compared with the accuracy of an electronic micro-processor.

However, to achieve maximum utilization with highest efficiency and least possible operational stops, it is very important that a hydraulic system be designed, manufactured, started and maintained absolutely correctly. The special factors vital to the user (purchaser) must also be understood if operation in the field is not to be plagued by stops and other disturbances.

Nearly all factory systems use "flowing energy" in production. More than half of all manufactured products are based on this form of energy, and it is therefore of interest to all manufacturers, exporters, purchasers, stockists, and repairers of production systems and machines, including agricultural machines and machine pools, the village smithy and the automobile industry, shipping and aviation.

Clearly, the knowledge and experience of many designers, producers, repairers and owners (users) is being outstripped by the dramatic development and rapid spread of hydraulics.

The purpose of this article is therefore not to try to provide patent solutions to all hydraulic problems, but to help create an understanding of why problems arise and what steps can be taken to avoid them.

Dimensioning

Reliable sizing provides the most optimal selection of components.

It is obvious that if undersized components are used, they will not operate under overload. They will be sensitive and become a frequent source of problems and complaints. More important still, in comparison with a correctly sized component an oversize component will probably operate problem-free and "effortlessly " for a very long time, but its original price will be too high.

If not able to carry out accurate calculations to obtain optimum conditions, the guidelines below are worth following.

The first thing to establish is the maximum operating pressure required for the system since this is the decisive factor in pump selection and, in turn, important as far as the size (output) of the prime mover and the system price are concerned. The higher the operation pressure, the higher the price of many of the components.

When the economic considerations have been made, particular types and sizes of operating cylinders, motors, and steering units to be used in the system can be considered.

The pump size is found by adding the necessary amounts of oil (expressed in liters per minute) that can be in use at the same time.

Consequently, the total is the amount the pump must be able to supply at the maximum intermittent operating pressure (= pressure relief valve setting pressure).

Size of pump

The power applied to the pump must be found as a function of the pressure in bar, revolutions per minute and flow in liters per minute, expressed in kW. The result can be used to find the size of motor that will safely yield the necessary output. See the following example.

Hydraulic output N = pressure x flow, i.e. N = px Q

Example:

$$N = \frac{p \times Q}{612} \quad [\,kW\,]$$

p = 150 bar

$$Q = 45 \text{ l/min} \quad N = \frac{150 \times 45}{612} = 11{,}03 \text{ kW}$$

When calculating the necessary pump output (Pnec), account must be taken of the total pump efficiency, (ηtot.) as stated in the catalog.

Example:

$$P_{an} = \frac{p \times Q}{612 \times \eta_t} = \frac{150 \times 45}{612 \times 0{,}9} = 12{,}25 \text{ kW}$$

$$V = \frac{Q \times 1000}{n \times \eta_{vol}} \quad Q = \text{l/min; } n = \text{min-1}$$

Sizes of pipes and hoses

The size depends on:
- maximum system pressure
- maximum oil flow
- length of pipe system
- environmental conditions

Pressure drop must be as small as possible. The greater the resistance in the system, the greater the operational loss. It is important to avoid those factors which cause pressure drop such as, for example,

Dimensioning

the use of angled screwed connections. Where possible, these should be replaced by elbows. If long lengths of pipe or high flow velocity are involved, then an increase in diameter up to the next size should be considered.

Remember that the dimensions stated for the hydraulic pipes are the external diameters and wall thicknesses. The internal diameters are equal to the external diameters minus 2x the wall thickness.

Remember that when the internal diameter is doubled the flow area of the pipe is quadrupled,

Now the oil capacity supplied per minute by the pump is known, along with the amount of oil the individual components must have. The next stage is the dimensioning of pipes and hoses. This is also very important as otherwise, generated cavitation (noise), heat generation, pressure drop and, in some cases, bursting can occur.

There are many people who are frightened of this dimensioning as they associate it, incorrectly, with difficult mathematical calculations. In actual fact, if the nomogram adjacent is followed when calculating pipe dimensions, it is incredibly simple.

In order to use the nomogram, the first stage is to know the oil flow in liters per minute. After this it has to be known whether the pipes and hoses in question are to be used as suction lines, pressure lines or return lines. This is because there are some recommended velocities of oil flow available for these categories. These values are as follows:

- Suction line 0.5 - 1.5 m/s
- Pressure line 3 - 10 m/s
- Return line 2 - 5 m/s

Using the nomogram

Place a ruler over the two outer columns, that is, the known oil flow and the required speed for the pipe type in question. Read off the nearest internal pipe diameter on the middle column. (See *Calculating on the tube diameter* on page 8.)

Depending on the maximum pressure a decision can also be made as to whether to use light or heavy hydraulic pipes and hoses. Here a large price difference is involved, especially with the associated fittings. See table of pipe dimensions and maximum working pressure.

Valves

Valves are used in all hydraulic systems. In simple systems maybe only a pressure relief valve (safety valve) and a single directional valve is used. Other systems might be more complicated and might involve a large number and wide variety of electronically controlled proportional valves.

It is probably within valves that the choice of components is widest and where it is easy to use and waste most money if wrong selections are made.

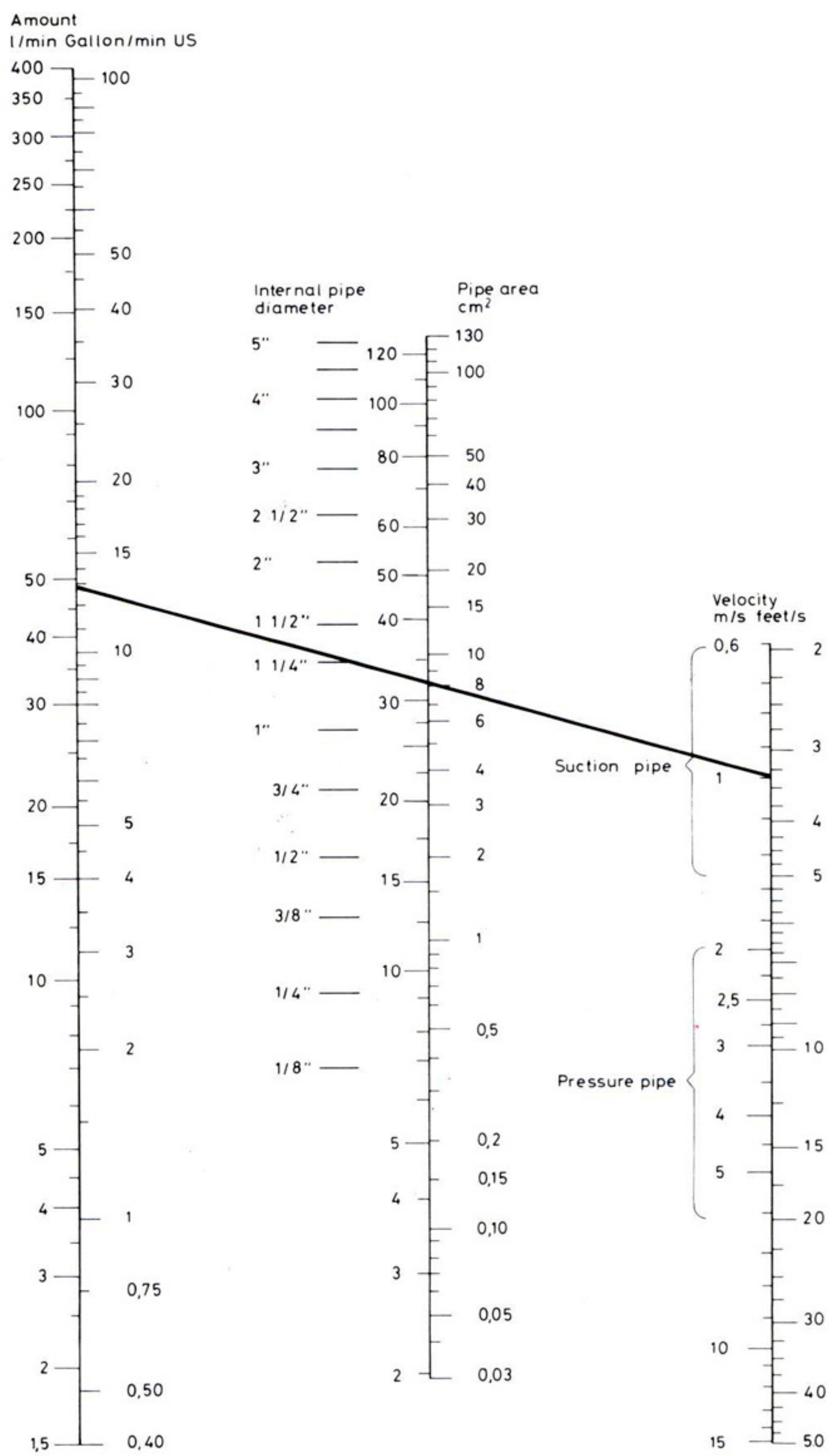
If in doubt, the suppliers of recognized makes of valves can be approached for advice on the selection. It is important not to select a valve which is too small or too large in relation to flow. If it is too small, the relative pressure drop will be too high, resulting in heat generation and possibly cavitation. If the valve is too large it can result in poor regulating characteristics causing the cylinder to not operate smoothly or the system to oscillate.

Dimensioning

Calculating on the tube diameter

Example:

- **Given volume** = 50 l/min
- **Given speed** = 1 m/s
- **Found diameter** = 32 mm

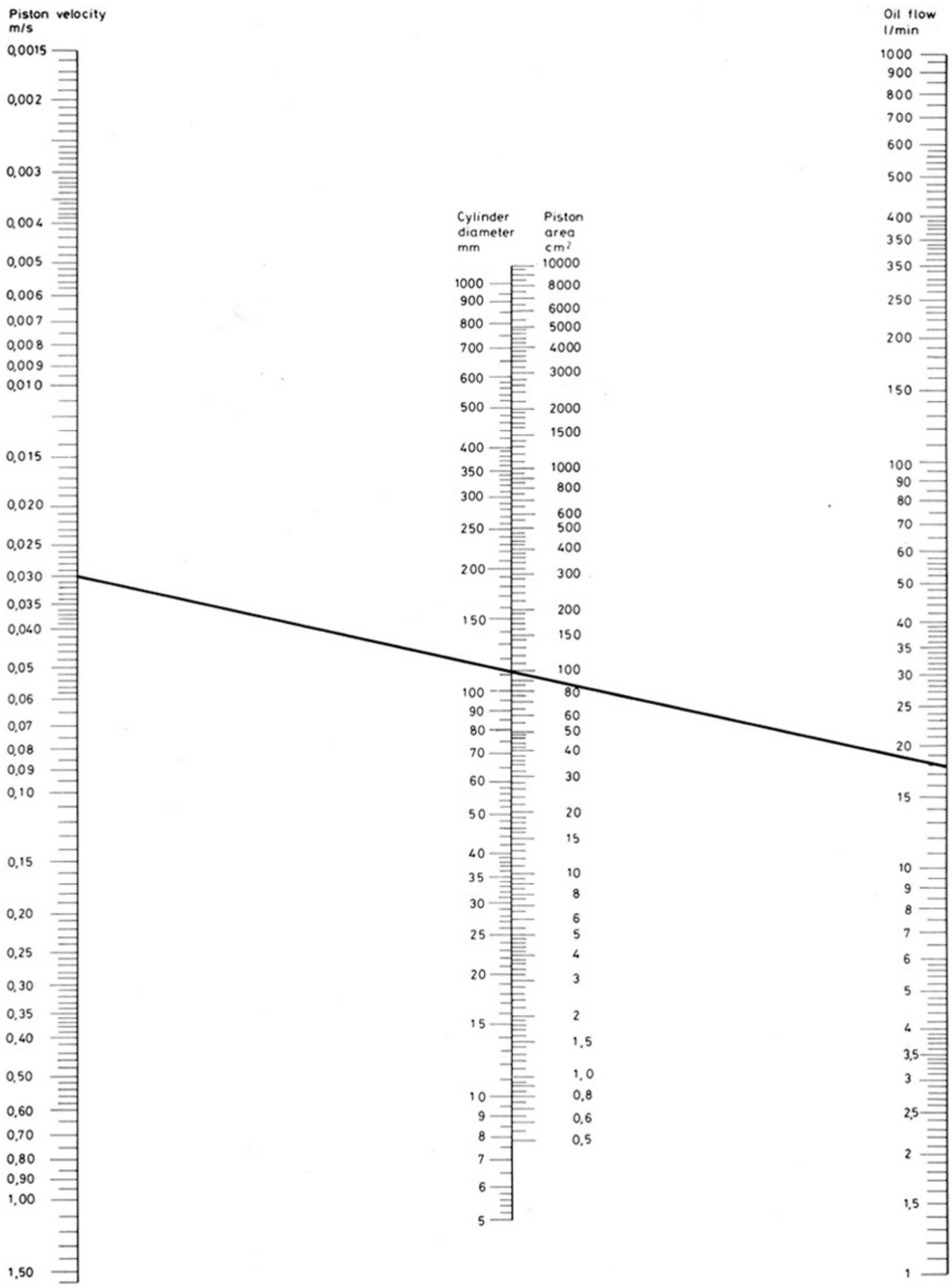


Dimensioning

Calculation of piston velocity - oil flow

Example:

- **Given piston velocity** = 0,03m/s
- **Given cylinder diameter** = 112 mm
- **Found pump capacity** = 18 l/min

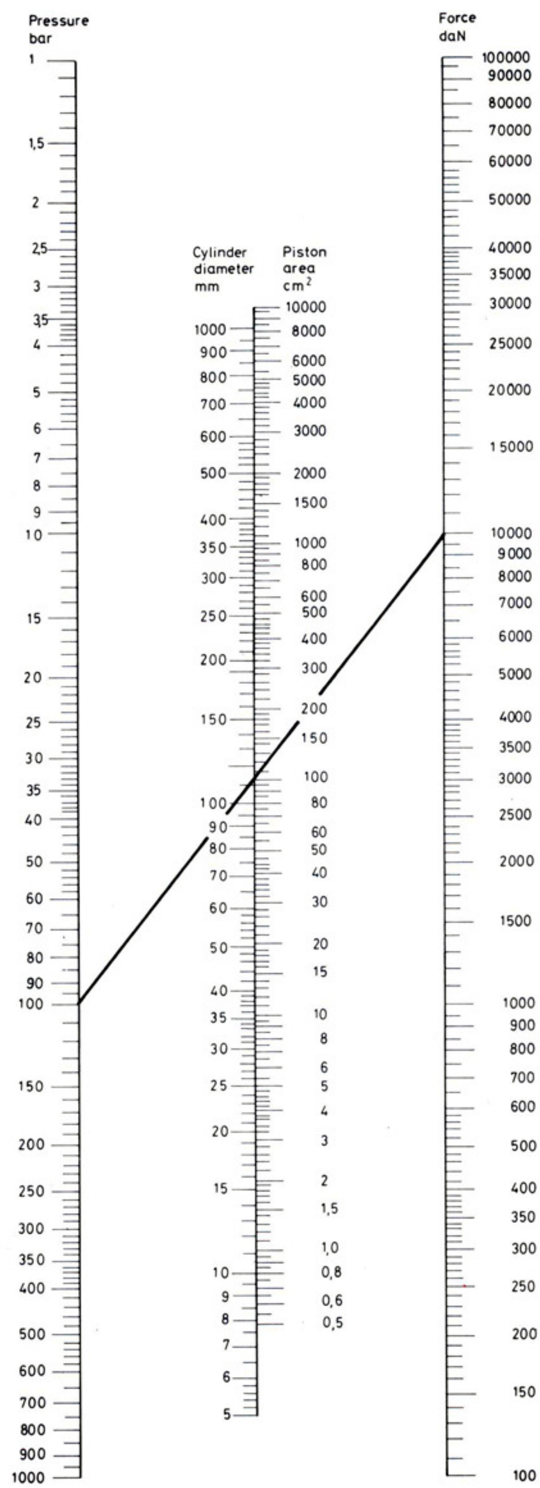


Dimensioning

Calculation of cylinder force

Example:

- **Given pressure** = 100 bar
- **Given cylinder diameter** = 112 mm
- **Found force** = 10.000 daN



Dimensioning

Table of cylinder power

Push: ▬► Pull: ◄▬

Cylinder	Piston area	Piston rod	Area, piston less piston rod	250 bar Push	250 bar Pull	210 bar Push	210 bar Pull	175 bar Push	175 bar Pull	140 bar Push	140 bar Pull	100 bar Push	100 bar Pull	70 bar Push	70 bar Pull
mm	cm²	mm	cm²	ton	ton	ton	ton	ton	ton	ton	ton	ton	ton	ton	ton
40	12,566	**22**	8,765	3,141	2,191	2,638	1,840	2,199	1,533	1,759	1,227	1,256	0,876	0,879	0,613
		28	6,409		1,602		1,345		1,121		0,897		0,640		0,448
50	19,635	**28**	13,478	4,908	3,369	4,123	2,830	3,436	2,358	2,748	1,886	1,936	1,347	1,374	0,943
		36	9,457		2,364		1,986		1,654		1,323		0,945		0,661
63	31,172	**36**	20,994	7,793	5,248	6,546	4,408	5,455	3,673	4,364	2,939	3,117	2,099	2,182	1,469
		45	15,268		3,817		3,206		2,671		2,137		1,526		1,068
80	50,265	**45**	34,361	12,566	8,590	10,555	7,215	8,796	6,013	7,037	4,810	5,026	3,436	3,518	2,405
		56	25,635		6,158		5,173		4,311		3,448		2,463		1,724
100	78,539	**56**	53,909	19,634	13,477	16,493	11,320	13,744	9,434	10,995	7,547	7,853	5,390	5,497	3,773
		70	40,045		10,011		8,409		7,007		5,606		4,004		2,803
125	122,71	**70**	84,233	30,677	21,058	25,769	17,689	21,474	14,741	17,179	11,793	12,271	8,423	8,589	5,896
		90	59,100		14,775		12,411		10,342		8,274		5,910		4,137
160	201,06	**90**	137,45	50,265	34,362	42,222	28,864	35,185	24,053	28,148	19,243	20,106	13,745	14,074	9,621
		110	106,03		26,507		22,266		18,555		14,844		10,603		7,422
200	314,16	**110**	219,13	78,540	54,782	65,973	46,017	54,978	38,347	43,982	30,678	31,416	21,913	21,991	15,339
		140	160,22		40,055		33,646		28,138		22,430		16,022		11,215

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 a system? Is it the:

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

When a hydraulic diagram is being prepared, the designer must have quality in mind, including the quality of the drawing itself, so that any errors in interpreting the drawing are avoided. It is a good idea always to use the correct ISO/CETOP-symbols.

When the diagram is subsequently used in preparing parts lists and accurate component specifications, sizing problems often occur. The designer is confronted with brightly colored brochures and catalogs and, at first, all is confusion. The temptation is to revert to rule-of-thumb methods and "add a bit for safety's sake", the result being a system which is either too expensive or is unstable and of poor quality.

All reputable hydraulic component manufacturers give real, usable values in their catalogs, not just theoretical desired values. The technical data in Danfoss catalogs always represent average values measured from a certain number of standard components. In addition to these data, the catalogs contain a mass of useful and explanatory information on selection, installation and starting up of components, together with a description of their functions. This information must, of course, be used as intended in order to avoid overload, too high a wear rate, and con sequent oil overheating and to avoid an over-dimensioned system with poor regulation at too high a price.

The tank

Let us look a little closer at an example system, starting with:

The tank, which has many functions, for example:

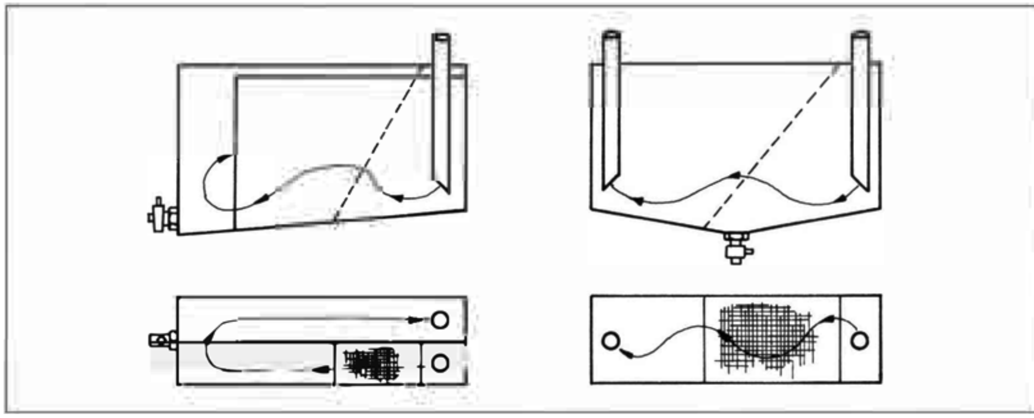
- as a reservoir for the system oil
- as a cooler
- as a "coarse strainer", sedimentation of impurities
- as an air and water separator
- as a foundation for pumps etc.

The dimensions of the tank and its form are important and it should 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. The arrangement to the left, is preferred as this increases the cooling effect as much as possible.

Selection of components

The tank functioning as a cooler - two arrangements



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 from 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 the tank oil level and must be easy to replace without significant spillage. That is to say, 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 top coats 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 oil 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 the hot hydraulic components. In consideration of the electronics a reduction of the maximum oil temperature to under 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 liters or several hundred liters in the system? Is it an expensive or a 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 is recommended by the component suppliers?

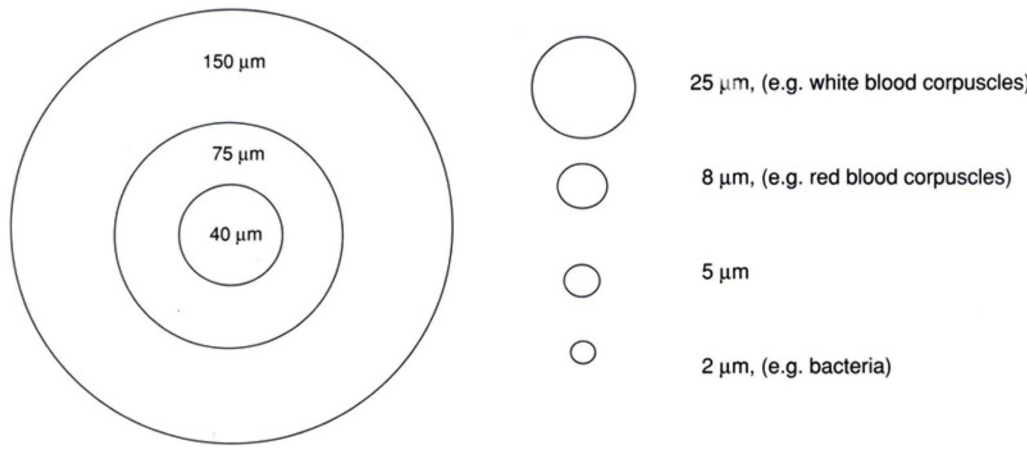
Filter types: Are suction filters, pressure filters or return filters to be used, or a combination of these with or without magnets? Is exclusive full-flow filtering involved, or will there also be bypass filtering through fine filters? Which type of dirt indicators are to be chosen, visual, mechanical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

Selection of components

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 than 40 µm) are as a rule, less dangerous than those that cannot be seen. It is often the hard particles of 5-25 µm, corresponding to normal hydraulic component tolerances, that are the most dangerous.

Relative size of particles



The naked eye is unable to see objects smaller than 40 µm.

For normal operation the degree of filtration for hydraulic products can generally be divided into the categories below:

Motors: 25, µm nominal - degree of contamination 20/16 (see ISO 4406) for return filter, or combined with a magnetic insert if a coarser filter is used, e.g. 40 µm.

Steering units: For systems having an efficient air filter and operating in clean surroundings, 25 µm nominal is adequate. If this is not the case 10 µm absolute - to 19/16 must be fitted Filters can be either pressure or return filters.

Proportional valves: In most cases, 25 µm nominal for return filter is adequate, but in systems especially subjected to contamination, a pressure filter is recommended to ensure operational reliability.

Radial piston pumps: In open as well as closed systems:

Suction filter: 100 µm nominal or finer, but not finer than 40 µm nominal.

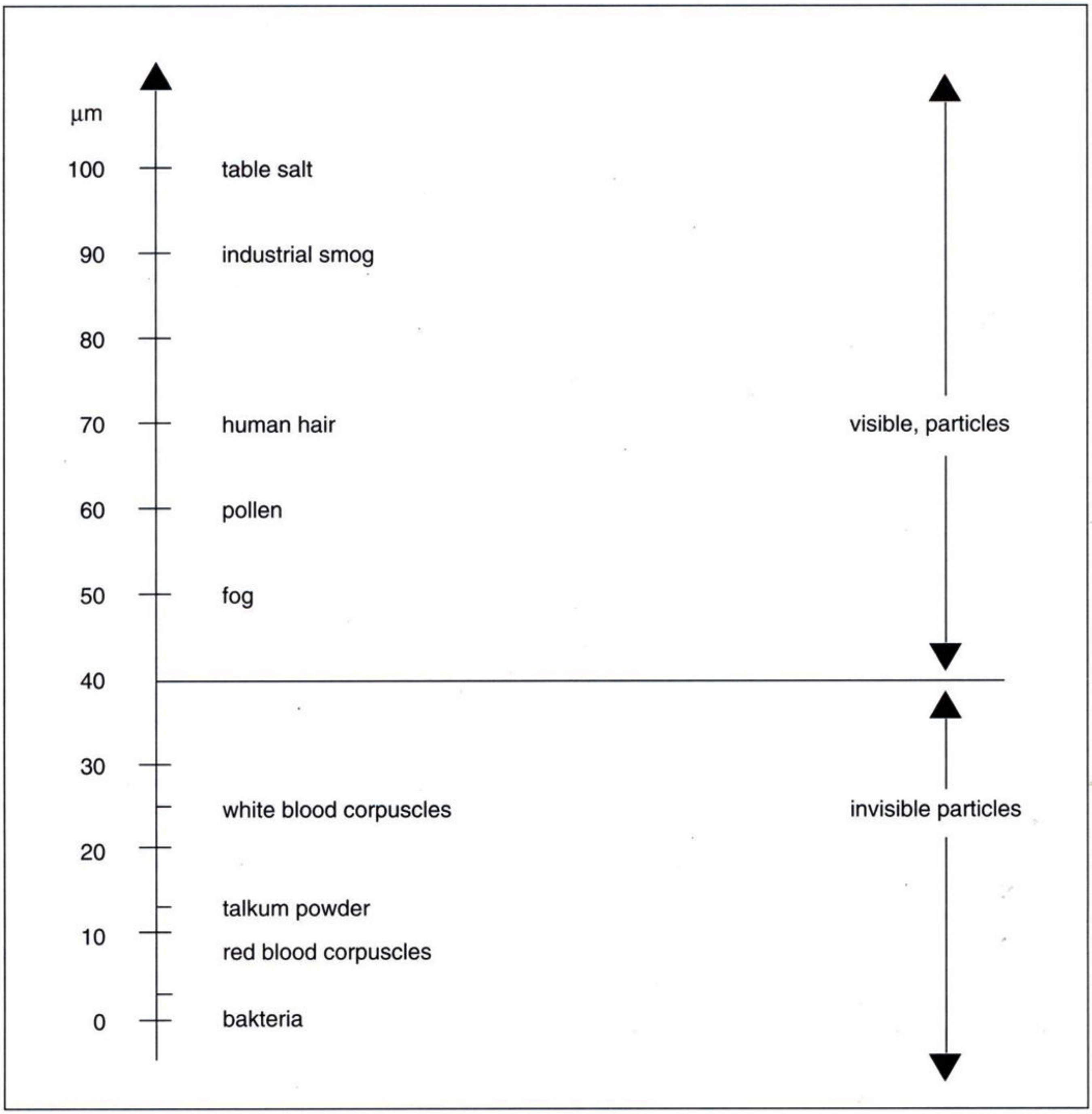
Return filter: 20 µm absolute or 10 µm nominal - 19/16.

Filters should be fitted with a dirt indicator so that operating conditions can be kept under observation. This is especially important with suction filters to avoid impermissible pressure drop in the suction line and consequent cavitation. The pressure in the suction line must not be less than 0.8 bar absolute.

Selection of components

Dimensions

Remember that drain lines from valves, motors etc. must also be led through the return filter to the tank. For pumps the drain oil pressure must not exceed 1 bar. Therefore the drain oil should bypass the filters.



Selection of oil type

Oil requirements

The oil in a hydraulic system must first and foremost transfer energy, but the moving parts in components must also be lubricated to reduce friction and consequent heat generation. Additionally the oil must lead dirt particles and friction heat away from the system and protect against corrosion.

Oil requirements:

- good lubricating properties
- good wear properties
- suitable viscosity
- good corrosion inhibitor
- good anti-aeration properties
- reliable air separation
- good water separation

Types of hydraulic-liquids

- Mineral oil
- Water
- Oil/water-emulsions
- Water/polyglycol mixture
- Synthetic liquids

Oil types

The most common hydraulic oil is a mineral based oil.

CETOP RP75H-class comprises following 4 groups:

- HH: oil without additives
- HL: oil with special additives for improving aging-durability and protecting against corrosion
- HM: "HL" + additives for improving wear-properties
- HV: "HM" + additives for improving the viscosity index

However, it can be an advantage to use other types of oils, especially in mobile systems such as tractors, etc. There is an advantage to be gained here from the use of the same oil for the diesel motor, the gearbox and the hydraulic system which often supply oil to both the working hydraulics and the steering. Other systems use transmission oil for the gearbox and hydraulics. In mines and off-shore installations, fire retarding liquids are used.

Non-inflammable fluids

Fire retarding hydraulic oils are sometimes classified as "non-inflammable hydraulic oils", but they will all burn under unfavorable conditions.

In water-based hydraulic oils it is solely the water that makes them fire retarding. When the water has evaporated, they can burn. Among synthetic fire retarding hydraulic oils, only phosphate esters are used.

It is important to select an oil type containing the correct additives, i.e. those which match the problem-free operation and long operating life for both hydraulic components and the oil itself can be ensured by following the maintenance instructions.

Additives

To improve the characteristics of a mineral oil, different kinds of additives are used. Normally the desire is to improve the following characteristics:

Selection of oil type

- Lubrication with metal/metal contact at high and low speeds
- Viscosity change must remain small in a wide temperature and pressure range. This characteristic is called the viscosity index (VI)
- Air solubility must be low and air emission high
- Foaming tendency must be low
- Rust protection must be high
- The toxicity of the oil and its vapor must be low

The amount and type of these additives are seldom given by suppliers, for such precise data are hardly of significance. The exception however, is anti-wear additives because these are important as far as avoiding seizing and prolonging the operating life of the system are concerned.

Danfoss recommends an ideal oil containing one of the following:

- 1.0-1.4% Dialkylzincdithiophosphate (tradename Lubrizol 677A)
- 1.0-1.6% tricresylphosphate (tradename Lindol oil)
- 1.0-1 .6% Triarylphosphate (tradename Coalite)
- Other additives producing similar effects

Motor oil

Motor oils and most transmission oils contain self-cleaning additives. These are a disadvantage in hydraulic systems.

For example, water condensed from the oil cannot be drained off; it forms an emulsion with the oil. This in turn leads to filters becoming clogged too quickly.

Selection of oil type

Viscosity classification system

The International Organization for Standardization (ISO) has developed a system viscosity classification system for industrial lubricating oil which Shell and the other large oil companies have decided to introduce (ISO 3448).

Viscosity diagram

ISO Viscosity Number		Middle viscosity in est at 40° C	Kinematic Viscosity limits in est at 40° C	
			Minimum	Maximum
ISOVG	2,00	2,20	1,98	2,42
ISOVG	3,00	3,20	2,88	3,52
ISOVG	5,00	4,60	4,14	5,06
ISOVG	7,00	6,80	6,12	7,48
ISOVG	10,00	10,00	9,00	11,00
ISOVG	15,00	15,00	13,50	16,50
ISOVG	22,00	22,00	19,80	24,20
ISOVG	32,00	32,00	28,80	35,20
ISOVG	46,00	46,00	41,40	50,60
ISOVG	68,00	68,00	61,20	74,80
ISOVG	100,00	100,00	90,00	110,00
ISOVG	150,00	150,00	135,00	165,00
ISOVG	220,00	220,00	198,00	242,00
ISOVG	320,00	320,00	288,00	352,00
ISOVG	460,00	460,00	414,00	506,00
ISOVG	680,00	680,00	612,00	748,00
ISOVG	1000,00	1000,00	900,00	1100,00
ISOVG	1500,00	1500,00	1350,00	1650,00

Checking the oil

Water in 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. If 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.

Oil oxidation

Normally an oil operating temperature of 30- 60C 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 an 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 0.1 liters of air per liter 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 color 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 layer. 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 stage 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 a 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 can be checked.

The presence of water

It is possible to make the following checks:

The presence of water can be detected as follows. Drain two or three cm^3 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 vapor when the small water 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 ¾ liters. The bottom of the can must be pushed slightly outwards and a burr-free hole of 4-5 mm drilled. Pour water which has been heated to 40 - 50°C into the can whilst keeping a finger over the hole. 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°).

Engler viscosity =

$$\frac{\text{drain time for oil}}{\text{drain time for water}} = E$$

See *Tables for conversing viscosity* on page 20.

The smell and appearance

The smell and appearance of an oil sample also reveals much about its condition, especially if it is compared with a sample of clean unused oil at the same temperature and in the same kind of glass

Checking the oil

container. By allowing two such samples to stand overnight, the bottom of the glass containing 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. ½ - 1 liter should be sent to a laboratory for a thorough check. Remember it is important that the bottles used for the samples are completely clean.

Tables for conversing viscosity

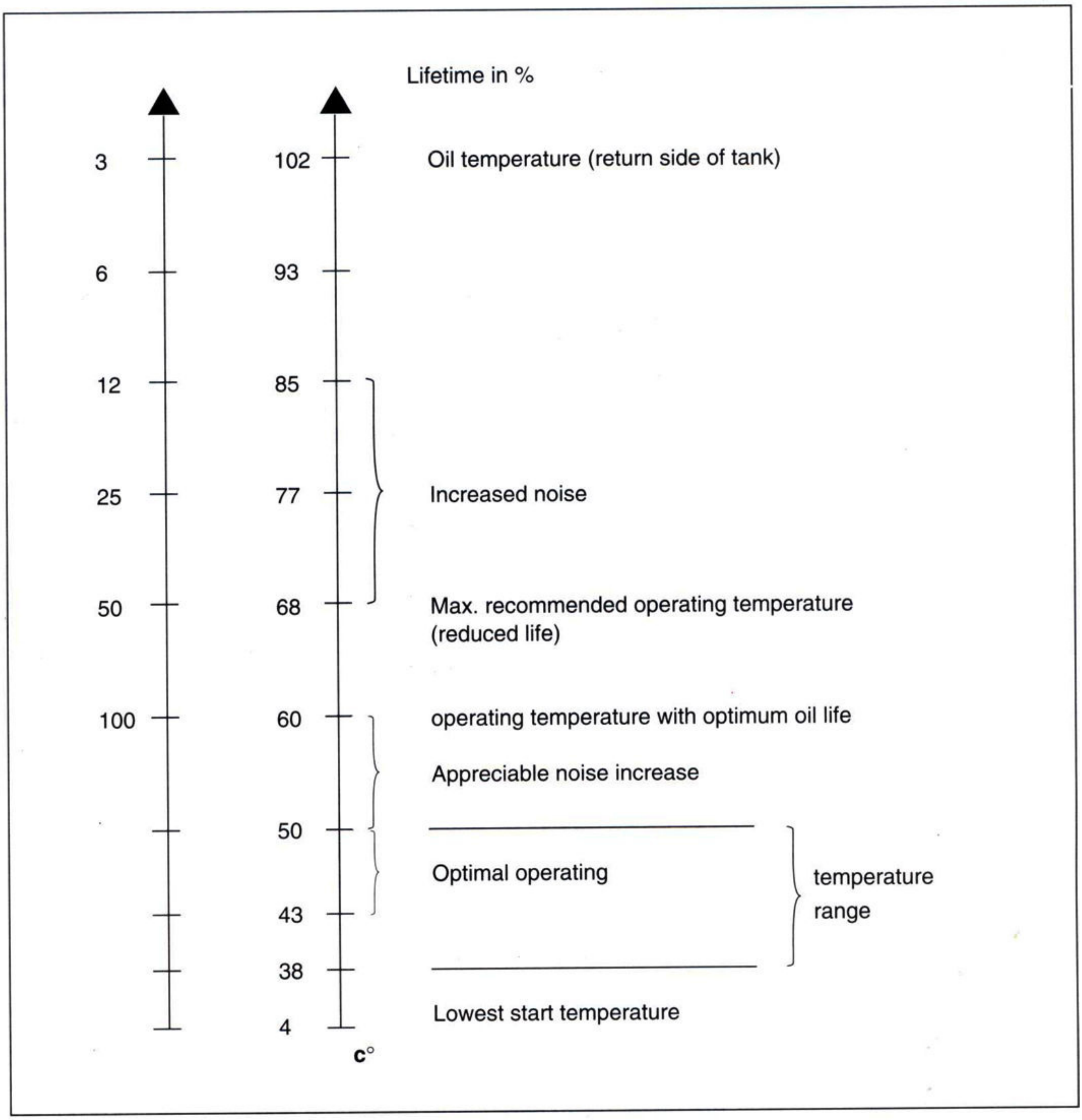
cSt = Centistoke E° = Engler° R = Redwood S = Saybolt

Conversing viscosity

cSt	E°	R	S	cSt	E°	R	S
1,00	1,00	26,7	29,3	26,00	3,58	109,1	123,6
1,50	1,07	28,4	31,3	27,00	3,71	113,0	128,0
2,00	1,12	30,3	33,1	28,00	3,83	117,0	132,4
2,50	1,17	31,7	34,8	29,00	3,96	120,9	136,8
3,00	1,22	33,0	36,5	30,00	4,09	124,8	141,3
3,50	1,27	34,5	38,0	31,00	4,21	128,8	145,7
4,00	1,31	35,8	39,5	32,00	4,34	132,7	150,2
4,50	1,35	37,1	41,0	33,00		136,6	154,7
5,00	1,40	38,5	42,5	34,00	4,58	140,6	159,2
5,50	1,44	39,7	44,0	35,00	4,71	144,4	163,7
6,00	1,48	41,1	45,4	36,00	4,83	148,8	168,2
6,50	1,52	42,4	47,0	37,00	4,96	152,5	172,8
7,00	1,57	43,8	48,6	38,00	5,09	156,5	177,3
7,50	1,60	45,2	50,2	39,00	5,22	160,5	181,9
8,00	1,65	46,5	51,8	40,00	5,34	164,5	186,5
8,50	1,70	48,0		41,00	5,47	168,6	191,0
9,00	1,75	49,4	55,1	42,00	5,60	172,6	195,6
9,50	1,79	51,0	56,8	43,00		176,6	200,2
10,00	1,83	52,4	58,5	44,00	5,86	180,7	204,8
10,50	1,88	53,9	60,2	45,00		184,7	209,4
11,00	1,93	55,4	62,0	46,00	6,11	188,7	214,1
12,00	2,02	58,5	65,6	47,00	6,25	192,8	218,7
13,00	2,12	61,8	69,3	48,00	6,37	196,8	223,3
14,00	2,22	65,1	73,1	49,00	6,50	200,8	227,9
15,00	2,32	68,4	77,0	50,00	6,63	204,8	232,6
16,00	2,43	71,8	81,0	51,00	6,76	208,9	237,2
17,00	2,54		85,0	52,00	6,88	213,1	241,8
18,00	2,65	79,0	89,2	53,00	7,01	217,2	246,5
19,00	2,76	82,8		54,00	7,15	221,3	251,1
20,00	2,88	86,7	97,6	55,00	7,27	225,3	255,7
21,00	2,99	90,4	101,9	56,00	7,40	229,4	260,4
22,00	3,10	94,0	106,2	57,00		233,4	365,0
23,00	3,22	97,8	110,5	58,00	7,67	237,4	269,6
24,00	3,35	101,5	114,9	59,00	7,79	241,4	27,,2
25,00	3,46	105,2	119,2	60,00	7,92	245,5	278,0

Checking the oil

Hydraulic oil temperature conditions oil life in %



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 environment 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 catalog instructions on pipes, hoses and fittings.

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

Remember 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. CLEANLINESS
2. CLEANLINESS
3. CLEANLINESS

Rule 1

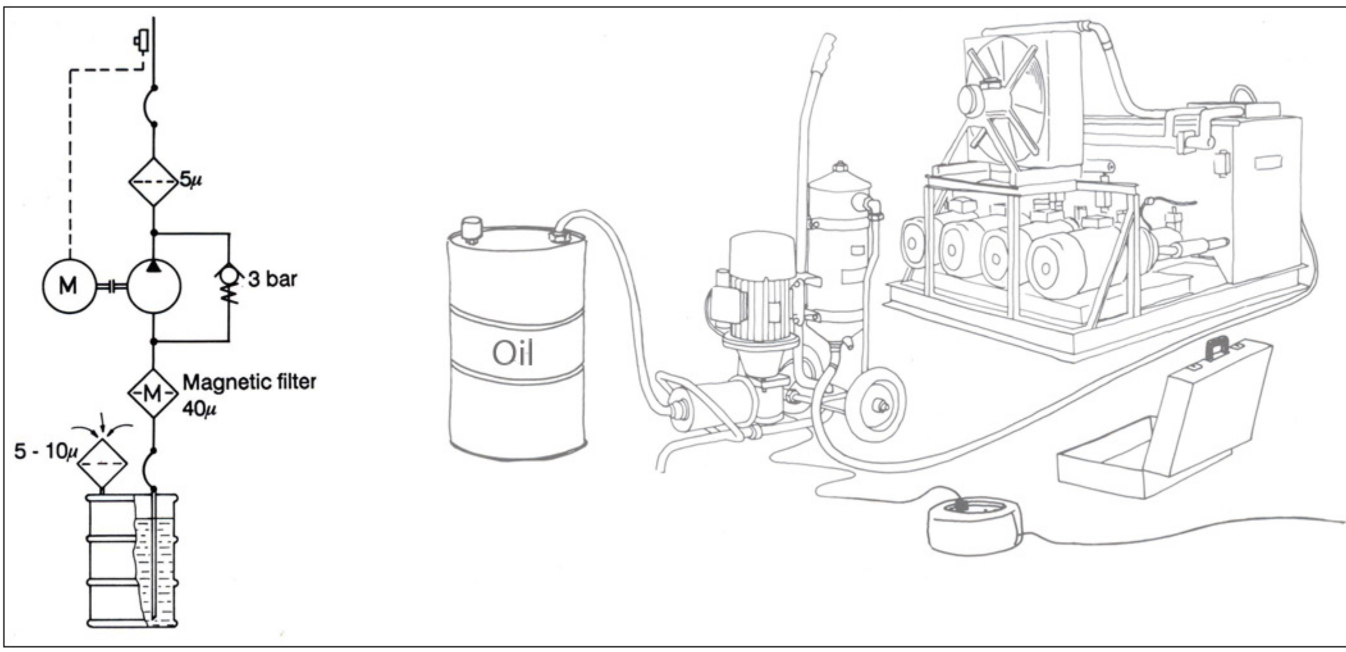
Concerns cleanliness during the installation of the hydraulic system. Hoses, pipes and fittings are never clean after being worked on and must therefore always be cleaned immediately prior to installation. Pipes, including pipe bends, should preferably be cleaned with a plug of crepe paper or lint-free cloth soaked in paraffin and blown through the pipe with com pressed 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 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 re moved until just before the components are installed.

Workshops, work stations, tools and clothing must also be as 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.

Installation of system

Fine filtration of the oil via a filling filter unit

Fine filtration of the oil via a filling filter unit is strongly recommended. When filling from drums there are nearly always too many particles in the oil, especially in the bottom where there is often a little water too. An example of a portable filling filter unit is shown below. It consists of a ¾ hk single phase electric motor driving a low pressure pump of 15-20 l/min capacity. The pump sucks from the oil drum through a pipe that can be screwed into the ¾ BSP drum connector. The diagonally cut end of the pipe extends to approx. 4-5 cm above the bottom. Oil is sucked through a 40 µm coarse strainer with magnetic insert and then through a 5 µm fine filter. The fine filter can be equipped with a low pressure switch that stops the pump when the filter is about to become saturated with dirt particles.



Installation of system

Rule 2

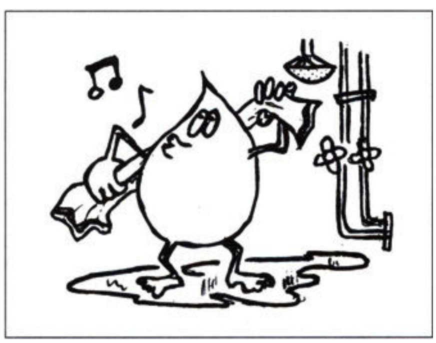
Concerns cleanliness during daily operation of a hydraulic system. Here, the main objective is to prevent the oil from becoming dirty. That is to say, filters (including air filters) must be clean - especially piston rods, shafts and shaft seals. It has been proven that on every square centimeter of piston rod area, one dirt particle of more than 10µm penetrates the cylinder. Imagine a piston rod of ⌀50 mm, a length of just 100 mm, and a velocity of 12 m/min. This means about 20.000 particles larger than 10 µm per minute!

The tools used for filling must of course be perfectly clean and the oil filled into the system must be filtered through filters of the same fineness as the finest in the system, normally 5 µm, but in any event no coarser than 10 µm 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 out doors so that water cannot collect around the plugs.

Rule 3

Concerns cleanliness during 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 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.



Starting up and running-in

Correct starting up and running-in is of the utmost importance in ensuring that the system runs for a long time without problems. All to often, many systems and especially pumps "die" after only a few hours running, some after only a few minutes, because the most elementary steps have been overlooked. One example is the non-observance of the cleanliness rules before and during start-up.

But despite even the best degree of cleanliness and care during installation, the presence of dirt in a new system cannot be avoided. During running-in, wear particles will be produced from all moving parts. It is therefore important not to apply full load to the system before this dirt has been filtered out.

Procedure for starting up

Let us look at our system which is fitted with a Danfoss pump type VPA and study the procedure for starting up:

1. Examine the tank to make sure it is perfectly clean internally. If it is not, clean it out with a vacuum cleaner. Often during installation, it is necessary to bore and tap a few extra holes which are not shown on the drawing.
2. Fill with clean oil of the correct type - through a filtering unit as described in *The return line and return filter* on page 27. If such a unit is not available, any filling funnels, cans, hoses must be thoroughly cleaned before they are used. Oil is filled through the return filter.
3. Before the pump is started, check the following:
   - Have all the flanges and screwed connections been tightened? (There is always one that hasn't').
   - Is the directional valve in its neutral position? (If it is not, the results can be catastrophic).
   - Is the pressure relief valve set at minimum? (The result of a leak or a malfunction is more violent at high pressure than at low pressure).
   - Does the pump rotate in the correct direction? (Nearly all pumps have a particular direction of rotation: clockwise or counterclockwise looking on the end of the output shaft. The direction ought to be clearly marked with an arrow. Many pumps will not withstand being rotated in the wrong direction for more than a few minutes).
   - Is the pump and any suction line filled with oil? (Some pumps cannot withstand being rotated for more than a few minutes without oil in the pump housing).
4. Connect a vacuum meter in the suction line, as close to the pump as possible. Connect a 250 bar pressure gauge to the high pressure side of the system. Connect a 5 bar pressure gauge to the upper drain connection. Pumps with a priming pump must be fitted with a 25 bar pressure gauge on the priming pump take-off. If there is more than one pump on the same shaft, each pump must be fitted with these pressure gauges.
5. If possible, connect the discharge side of the pump to the tank, otherwise to a 5-10 liter container.
6. Set the pump displacement to at least 40% of maximum.
7. Start the pump (with a combustion engine at 800-900 r/min, or with an electric motor having short - duration start/stop functions). When the pump starts to suck (oil runs into the tank or container) stop the pump and connect its pressure outlet to the high pressure side of the system.
8. If the pump does not suck relatively quickly, check the following:
   - Is the suction line leaky?
   - Is there free flow in the suction line?
   - Does the pump rotate at all?

   Is the pump set for minimum 40% displacement?
9. Start the pump once more. Operate each directional valve for each motor or cylinder one after another, with a necessary bleeding at as low a pressure as possible. Repeat until the return oil in the tank does not foam and the motors and cylinders operate smoothly. Check the oil level frequently and refill with filtered oil.
10. A further frequent check: make sure that the suction pressure is at least 0.8 bar absolute, corresponding to 0.2 bar on the scale. After a short time, the drain pressure must be maximum 1 bar.

Starting up and running-in

11. Set the pump for maximum displacement and the motor for maximum speed (but not higher than 3150 r/min continuous) and allow the system to run unloaded for about 20 minutes, until the oil temperature has stabilized. Reverse the direction of the motor and the travel of the cylinders frequently.
12. Set the individual pressure relief valves and the pump pressure control valve at the specified pressure. Any shock valves in the system must be set at approx. 30-40 bar over the constant operating pressure. Check the oil temperature.
13. If required, the pump maximum oil flow can be set using the flow limiter.
14. Remove the pressure gauges and vacuum meter and insert plugs in the connections. Replace filter inserts with new ones. Check the oil level.
15. If there is a large amount of oil (for example, more than 100 liters in the system), an oil sample can be taken and sent to the oil supply firm for analysis.
16. The system can now be put to work.

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 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 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, the oil by looking at its color. 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 or emulsified water. And of course the oil might contain free 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 armored 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.

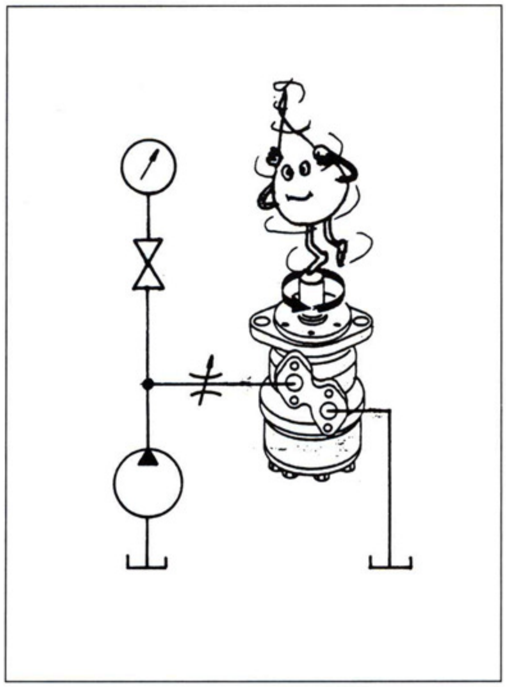
There must be no leaks. Look on the floor under the vehicle for oil patches. The finger tips are good instruments for sensing faults, the ears too - by using a screwdriver or similar tool as a stethoscope, irregularities which might later cause breakdown can often be heard.

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 condition of the filter can easily be seen. If there is no dirt indicator, the filter has to be taken out to see whether it needs cleaning or replacement.

Fault location

Under this heading, it is obvious that the two basic factors, pressure and flow, must be in accordance with specifications. If the opposite is true nothing will function perfectly. If the condition of the pump is suspect, the pressure line from the system must be disconnected and a pressure gauge fitted, together with a throttle valve and flow meter, as shown in the sketch below.



If no flow meter is available, a Danfoss hydraulic motor can be fitted instead. The displacement of the motor per revolution with unloaded shaft is very precise and to find flow all that is necessary is to count the number of revolutions per minute and multiply the figure by the displacement, as shown in the following examples:

Example 1: OMR 100:

$$\frac{\text{Rev./min.} \times 100}{1000} = \text{l/min} \qquad \frac{220 \times 100}{1000} = 22 \text{ l/min}$$

Example 2: OMR 315:

$$\frac{\text{Rev./min} \times 315}{1000} = \text{l/min} \qquad \frac{116 \times 315}{1000} = 36{,}5 \text{ l/min}$$

Pump test

Check the flow with completely open throttle valve.

Increase the throttle until it corresponds to normal operating pressure.

Again check the flow and compare it with the values given in the pump catalogue.

The volumetric efficiency of the pump can be calculated thus:

$$\eta_{\text{Vol.}} = \frac{\text{flow with operating pressure}}{\text{flow with no pressure}}$$

If the capacity with operating pressure, and thereby the µ vol. is too low, the pump has internal leakage - as a rule because of wear or seizing.

Fault location

Fault location general

THINK before starting fault location!

Every fault location process should follow a logical and systematical order. Usually it is wisest to start at the beginning:
- Is the oil level correct when the pump is operating?
- Is the condition of oil and filters acceptable?
- Are pressure, flow and flow direction as specified?
- Is the oil temperature too high or too low (oil viscosity)?
- Are there any unrequired vibrations or noise (cavitation)?

If the driver of the vehicle is available ask him:
- what type of fault it is and how it affects the system
- how long he has felt that something was wrong
- whether he has "fiddled" with the components
- whether he has any hydraulic and electrical diagrams available.

Diagrams are often found in the instructions included with vehicles/machines. Unfortunately they are often so schematic that they are not of much use in a fault location situation. However, the order of and the connections between the individual components are often shown.

When a defect component has, with certainty, been found both the component and its surroundings must be cleaned before removal. Loose paint must also be removed from pipes and fittings.

Holes, hoses and pipe ends must be blanked off with plugs or sealed with, for example, plastic bags after removal to avoid the entry of dirt during standstill. Never dismantle hydraulic components outside. We recommend that repairs be carried out in a workshop on a clean workbench perhaps covered with newspaper.

Make sure that a Danfoss service manual dealing with the product in question is handy. Follow the instructions word for word both when dismantling and assembling because if these instructions are not followed closely serious faults may develop. NB. In some cases special tools are necessary for assembling. Our service manuals give full guidance as to when this is the case.

Hydraulic pumps

Hydraulic pumps fault location tips

Fault	Possible cause	Remedy
Pump noisy	No or insufficient oil supply to pump.	Clean suction filter. Check that no damage or narrowing is to be found on suction line.
	Viscosity of oil too high.	Change the oil, adjust viscosity to working temperature.
	Pump takes in air: • At the pump shaft. • At loose or damaged suction line. • Oil level too low. • Oil takes in air in the tank (return pipe discharging over oil surface).	Replace shaft seal. Tighten fittings or replace suction line. Refill with clean oil. Extend return pipe to 54 cm under the surface and as far as possible from the suction pipe.
	Pump worn out.	Repair or replace pump.
	R.P.M. too high.	Adjust the R.P.M.
	Oil pressure too high.	Adjust oil pressure.

Fault location

Hydraulic pumps fault location tips (continued)

Fault	Possible cause	Remedy
No pressure	Oil level too low.	Refill with clean oil.
	Pump does not run or runs in the wrong direction.	Adjust direction of rotation. Check driving belt or coupling.
	Relief valve is stuck in open position.	Repair relief valve.
	Pump defective, broken shaft or key for rotor.	Repair pump.
No or unstable pressure	Working pressure too low	Check pressure adjusting valve.
	Leaky pressure adjusting valve or pilot valve.	Repair valve.
	The oil flows more or less to the tank through defective valve or cylinder.	Repair cylinder or valve.
Noise and relief valve	Excessive flow.	Fit a larger valve corresponding to the actual oil volume.
	Dirt or chips between valve cone and valve seat.	Repair valve.
Air in the system, foam in the oil	Leaky suction line.	Re-tighten or replace pipe.
	Excessive resistance in suction line.	Clean filter and suction line, or replace with pipes having larger bores. Check fittings.
	Return line discharges above the oil level - could cause foam formation. and extend if necessary.	Remove return line from suction line.
	Incorrect oil type.	Change over to correct oil type.
Overheated system	No supply of cooling water.	Re-establish supply of cooling water.
	Oil cooler blocked or dirty.	Clean oil cooler.
	Excessive oil viscosity.	Change over to correct oil type.
	Abnormal internal leakage in one or more components.	Repair or replace defective components.
	Altered running conditions.	Establish extra cooling if necessary.
	Pump, valves or motor overloaded.	Reduce load or replace component with a bigger one.

Hydraulic motors

Hydraulic motors fault location tips

Fault	Possible cause	Remedy
R.P.M. of motor lower than rated value	Pump worn out.	Repair or replace pump.
	R.P.M. of pump too low.	Adjust the R.P.M.
	Motor worn out.	Repair or replace motor.
	Oil temperature too high (resulting in excessive internal leakage in motor, valves, etc.). Possibly too high ambient temperature.	Build in oil cooler or increase existing cooler or tank capacity. If necessary change over to oil with a higher viscosity.
	Insufficient diameter in pipes, etc.	Fit lines with larger diameter.
	Pump cavitation.	See under: Pump noise.
	Opening pressure of pressure relief valve too low.	Adjust to correct pressure.
	Leaky control valve.	Repair valve.
	Overloaded motor.	Eliminate the cause of the overload or change over to larger motor.

Fault location

Hydraulic motors fault location tips (continued)

Fault	Possible cause	Remedy
Motor shaft does not rotate	Pump does not run or runs in the wrong direction.	Start pump or reverse direction of rotation.
	Motor spool has seized in housing.	Replace complete shaft and housing.
	Cardan shaft or spool broken (shaft and commutator valve in two).	Replace cardan shaft or complete shaft and housing. Eliminate external forces which caused the fracture.
	Working pressure too low.	Adjust opening pressure of relief valve to higher value, however, within permissible limits. If necessary, change over to motor with higher torque.
	Sand, steel chips or similar impurities in motor.	Clean the motor, and flush system thoroughly. Renew defective parts. Use a better filter.
Motor shaft rotates in the wrong direction	Oil lines are wrongly connected to direction motor ports.	Change the connections.
	Gear-wheel and rotary valve incorrectly fitted.	Adjust settings.
Leakage at motor shaft	Shaft seal worn out or cut.	Replace shaft seal.
Leak between motor spigot and housing	Spigot is loose.	Tighten screws with prescribed torque.
	O-ring defective.	Replace O-ring.
Leaks between housing, spacer plate, gear wheel set and end cover, respectively	Screws loose.	Tighten screws with prescribed torque.
	O-rings defective.	Replace O-rings.
	Steel washers defective.	Replace steel washers.

Steering systems with OSPB - OSPC - OVP/OVR - OLS

Follow these quick methods of testing steering systems:

1. Start the motor (pump) and let it run for a couple of minutes.
2. Drive slowly in a figure of eight. Pay special attention to any shaking or vibration in the steering wheel or steered wheels. See whether the steering wheel movements are immediately followed by a corresponding correction of the wheel movements, without any "motoring" tendencies.
3. Stop the vehicle and turn the steering wheel with small quick movements in both directions. Let go of the steering wheel after each movement. The steering wheel must immediately go back to the neutral position, specifically there should be no "motoring" tendencies.
4. While the vehicle is still stationary turn the steering wheel from stop to stop. Count the number of times the steering wheel turns in both directions.

   It must be possible to turn the steering wheel with one finger.

   Stop the motor (pump) and again turn the steering wheel from stop to stop. Again count the number of turns and compare with previous figures. If there is a large difference (1 turn or more) the leakage in the cylinder, gear wheel set, shock valve or suction valve is too large.

   With larger vehicles where there is no emergency steering function, turn the steering wheel whilst the motor is idling.
5. If there is a leak, remove a hose from one of the cylinder ends and plug this and the hose. Try to turn the steering wheel again. If the wheel cannot turn the cylinder is defective. If this is not the case the steering unit or valve block is defective.

Fault location

Steering units OSPB - OSPC - OVP/OVR - OLS

Steering units OSPB - OSPC - OVP/OVR - OLS

Fault	Possible cause	Remedy
Steering wheel is heavy to turn	No or insufficient oil pressure	
	Pump does not run	Start up pump (loose V-belt)
	Pump defective	Repair or replace pump
	Pump runs in the wrong direction replace pump	Correct direction of rotation of pump
	Pump is worn out Pump is under dimensioned	Replace pump. Install a larger pump (examine pressure need and flow).
	Pressure relief valve is stuck in open position or setting pressure is too low.	Repair or clean pressure relief valve. Adjust the valve to the correct pressure.
	Priority valve is stuck in open position.	Repair or clean the priority valve.
	Too much friction in the mechanical pans of the vehicle.	Lubricate bearings and joints of steering gear or repair if necessary. Check steering column installation.
	Emergency steering balls missing.	Install new balls.
	Combination: Downstream system+ steering unit with suction valve and differential cylinder are inexpedient.	Change cylinder type (through going piston rod). If necessary use two differential cylinders.
Regular adjustments of the steering wheel are necessary ("Snake-like driving")	**1.** Leaf spring without spring force or broken. **2.** Spring in double shock valve broken. **3.** Gear wheel set worn. **4.** Cylinder seized or piston seals worn.	**1.** Replace leaf springs. **2.** Replace shock valve. **3.** Replace gear wheel set. **4.** Replace defective parts. .
Neutral position of steering wheel can-not be obtained, for instance there is a tendency towards "motoring"	**1.** Steering column and steering unit out of line. **2.** Too little or no play between steering column and steering unit input shaft. **3.** Pinching between inner and outer spools.	**1.** Align the steering column with steering unit. **2.** Adjust the play and, if necessary shorten the splines journal. **3.** Contact the nearest service shop.
"Motoring" effect. The steering wheel can turn on its own.	**1.** Leaf springs are stuck or broken and have therefore reduced spring force. **2.** Inner and outer spools pinch, possibly due to dirt. **3.** Return pressure in connection with the reaction between differential cylinder and steering unit too high.	**1.** Replace leaf springs. **2.** Clean steering unit or contact the nearest service shop. **3.** Reduce return pressure, change cylinder type or use a non-reaction control unit.
Backlash	**1.** Cardan shaft fork worn or broken. **2.** Leaf springs without spring force or broken. **3.** Worn splines on the steering column.	**1.** Replace cardan shaft. **2.** Replace leaf springs. **3.** Replace steering column.
"Shimmy"-effect. The steered wheels vibrate. (Rough tread on tires gives vibrations).	Air in the steering cylinder.	Bleed cylinder. Find and remove the reason for air collection.
	Mechanical connections or wheel bearings worn.	Replace worn parts.

Fault location

Steering units OSPB - OSPC - OVP/OVR - OLS (continued)

Fault	Possible cause	Remedy
Steering wheel can be turned the whole time without the steered wheels moving.	Oil is needed in the tank.	Fill with clean oil and bleed the system.
	Steering cylinder worn.	Replace or repair cylinder.
	Gear wheel set worn.	Replace gear wheel set.
	Spacer across cardan shaft forgotten.	Install spacer.
Steering wheel can be turned slowly in one or both directions without the steered wheels turning.	One or both anti-cavitation valves are leaky or are missing in OSPC or OVP/OVR.	Clean or replace defective or missing valves.
	One or both shock valves are leaky or are missing in OSPC or OVP/OVR.	Clean or replace defective or missing valves.
Steering is too slow and heavy when trying to turn quickly.	Insufficient oil supply to steering unit, pump defective or number of revolutions too low.	Replace pump or increase number of revolutions.
	Relief valve setting too low.	Adjust valve to correct setting.
	Relief valve sticking owing to dirt.	Clean the valve.
	Spool in priority valve sticking owing to dirt	Clean the valve, check that spool moves easily without spring.
	Too weak spring in priority valve	Replace with a stronger spring (There are 3 sizes: 4, 7 and 10 bar).
"Kick-back" in steering wheel from system. Kicks from wheels.	Fault in the system.	Contact vehicle supplier or Danfoss.
Heavy kick-back in steering wheel in both directions.	Wrong setting of cardan shaft and gear wheel set.	Correct setting as shown in Service Manual.
Turning the steering wheel activates the steered wheels opposite.	Hydraulic hoses for the steering cylinders have been switched around.	Reverse the hoses.
Hard point when starting to turn the steering wheel.	Spring force in priority valve too weak.	Replace spring by a stronger (4, 7 and 10 bar).
	Air in LS and /or PP pipes.	Bleed LS and PP pipes.
	Clogged orifices in LS or PP side priority valve.	Clean orifices in spool and in connecting plugs for LS and PP.
	Oil is too thick (cold).	Let motor run until oil is warm.
Too little steering force (possibly to one side only).	Pump pressure too low.	Correct pump pressure.
	Too little steering cylinder.	Fit a larger cylinder.
	Piston rod area of the differential cylinder too large compared with piston diameter.	Fit cylinder with thinner piston rod or 2 differential cylinders.
Leakage at either input shaft, end cover, gear-wheel set, housing or top part.	Shaft defective.	Replace shaft seal, see Service Manual
	Screws loose.	Tighten screws, torque 3-3,5 daNm or steering unit (2,5-3 daNm).
	Washers or 0-rings defective.	Replace washers and 0-rings.

Fault location

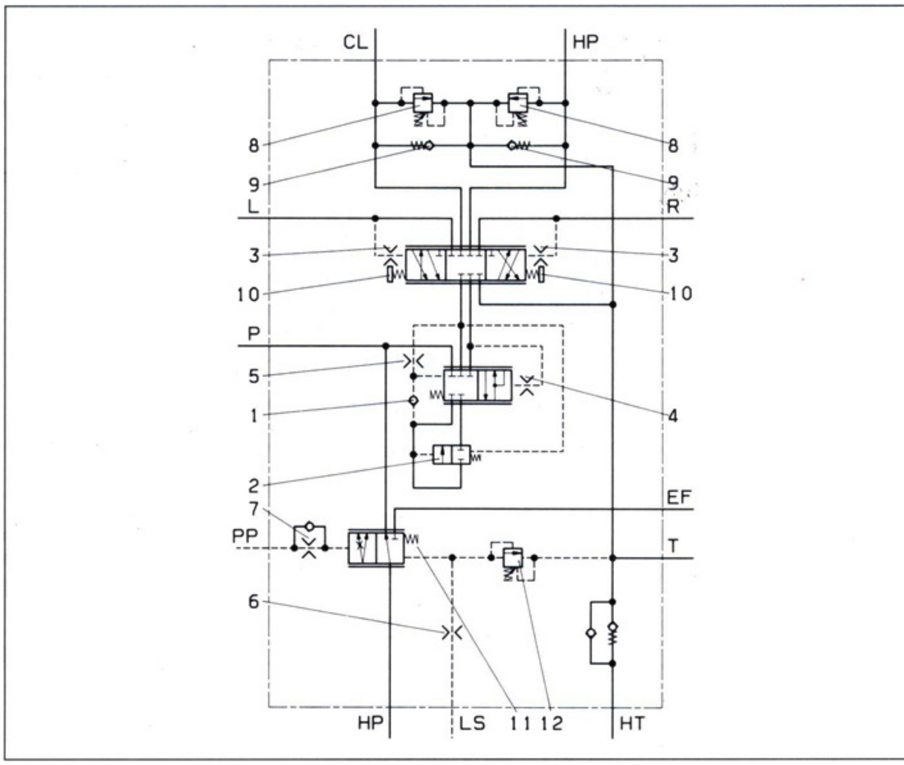
Steering systems with OSQA/B and OSPBX-LS

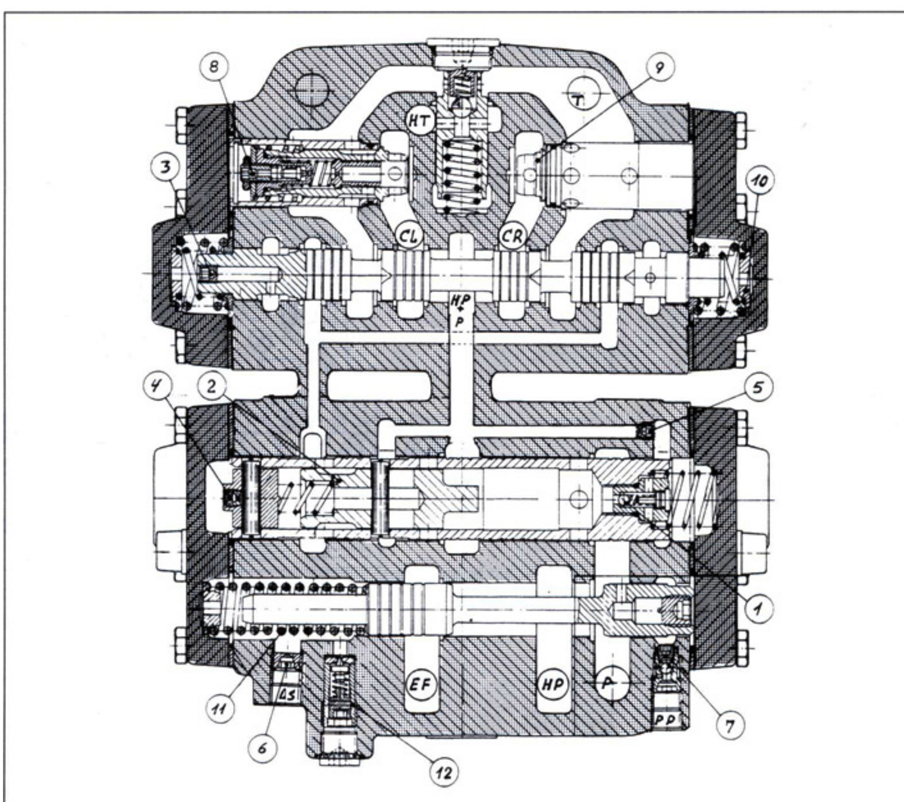
Steering systems with OSQA/B and OSPBX-LS fault location tips

Fault	Possible cause	Remedy
Amplification too large.	**1.** Dirty, leaky or missing check valve(1). **2.** Piston (2) sticks in the open position.	**1.** Clean or replace check valve. **2.** Clean and check that the piston moves easily.
Amplification too small.	**1.** Piston(2) sticks in the closed position **2.** Piston (2) incorrectly installed (only OSQA/B-5).	**1.** Clean and check that the piston moves easily. **2.** Rotate the piston 180° on its axis.
Heavy turning of steering wheel and slow increase of amplification.	**1.** Dirty orifices (3) in directional valve. **2.** Dirty orifice(4) in the combi-valve spool. **3.** Dirty orifice (5) in housing. **4.** Dirty orifice (6) in LS-port. **5.** Dirty orifice in throttle/check valve (7) in PP-port.	**1.** Clean or replace orifice. **2.** Clean or replace orifice. **3.** Clean or replace orifice. **4.** Clean or replace orifice. **5.** Clean or replace throttle/check valve.
No end stop in one or both directions.	**1.** One or both shock valves (8) set too low. **2.** One or both anti-cavitation valves(9) leaky, or sticking. **3.** Missing end-stop plate (s) (pas. 10) for directional valve.	**1.** Setting takes a long time without special equipment. Contact the nearest service shop. **2.** Clean or replace completely shock/anti-cavitation valve(s). **3.** Fit end-stop plates.
"Hard" point when starting to turn the steering wheel.	**1.** Air in LS and/or PP pipes. **2.** Spring force in the built in priority valve too weak(11). **3.** Orifices in respectively LS-(6) or PP- (7) ports blocked.	**1.** Bleed pipes. **2.** Replace spring by one which is more powerful. (There are three sizes: 4, 7 and 10bar). **3.** Take out and clean orifices.
No pressure build-up.	**1.** LS-pressure limitation valve(12) adjusted too low. **2.** Spool and sleeve in OSPBX steering unit put together incorrectly. **3.** Emergency control ball in steering unit missing Pump does not run or is defective.	**1.** Remove plug and set to specified pressure. **2.** Take out spool set and turn the inner spool 180° in the outer sleeve. (See Service Manual) **3.** Install new ball. **4.** Repair or replace pump.

Fault location

Faults locations illustrations





Repair and testing

Repair

After fault location has revealed which system component is defective, that component must be removed and possibly replaced as a new or repaired one. Before removal , both the component and its surroundings must be cleaned and hoses or pipe ends blanked off with plugs or sealed with plastic bags, etc. to avoid the entry of dirt during standstill. The decision now to be made is whether the component is to be repaired domestically or by the producer. If the concerned component is from Danfoss, we recommend that it be repaired in one of our many service workshops (see list on back page). This particularly applies to more complicated components like steering units, flow amplifiers, pumps and proportional valves. For safety reasons, these all need testing with special equipment after

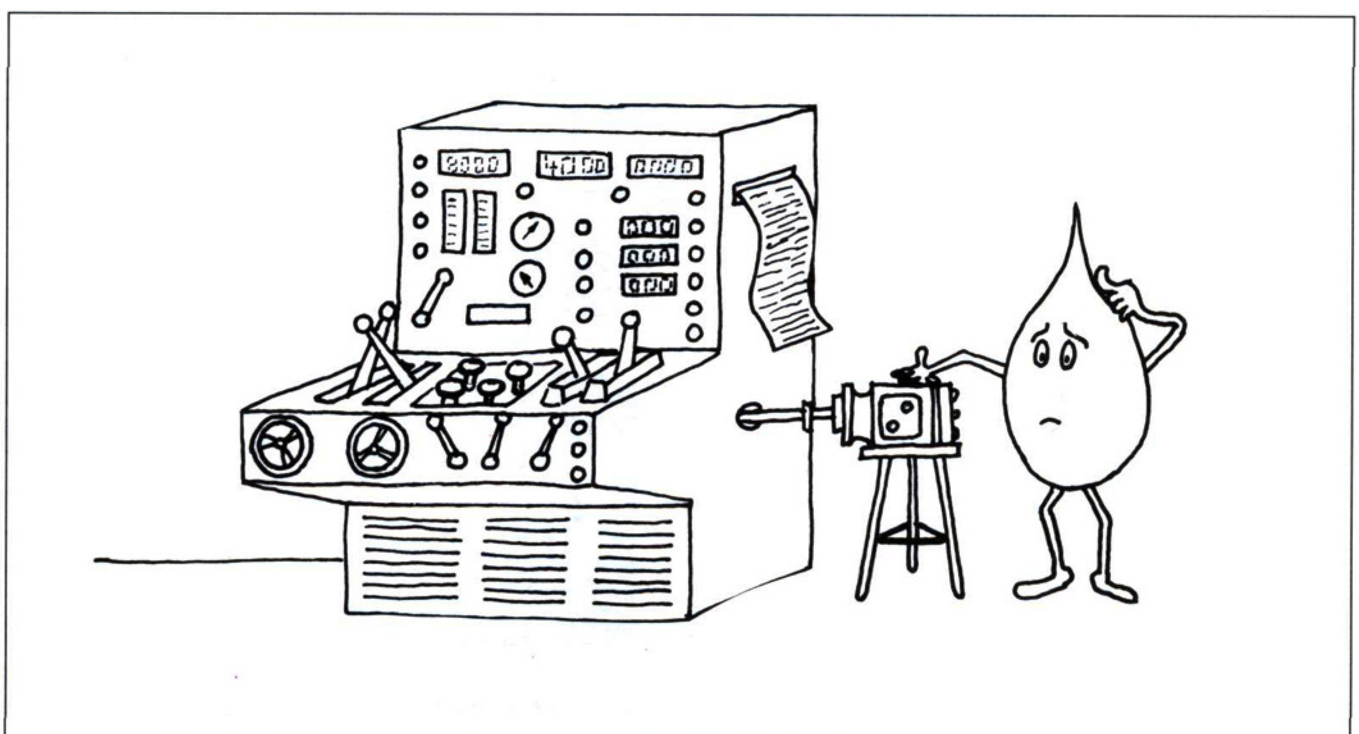
Of course situations can occur where components require immediate repair. We recommend most strongly that in such circumstances repairs be carried out only in very clean surroundings, in suitable premises on a tidy workbench perhaps covered with newspaper.

Caution

Dismantling and assembly must only be performed if the repairer has the associated Danfoss service manuals. If these are not followed, serious faults might develop; faults that could give rise to accidents. This is more than likely with steering components and proportional valves.

Testing

In general, all hydraulic components that have been dismantled ought to be tested on a suitable test panel to reveal possible assembly errors. If this is impossible, testing must be performed on the system.



Symbols and Tables

Symbols

Symbols

q =	Displacement	: cm^3
n =	Revolutions	: min^1
p =	Pressure	: bar
Δp =	Pressure drop	: bar
Q =	Oil capacity	: l/min = dm^3/min
v =	Speed	: m/s
l =	Length	: m
D =	Piston diameter	: mm
d =	Piston rod diameter	: mm
Di =	Bore of pipe	: mm
Dh =	Hydraulic diameter	: mm
A =	Area	: cm^2
a =	Ring area	: cm^2
t =	Time	: s.
m =	Volume	: kg
F =	Force	: N
M =	Torque	: Nm
P =	Power	: kW
A_s =	Break load	: daN
E =	Elasticity module	: kp/cm^2
l =	Free column length	: m
S =	Safety factor	
v =	Kinematic viscosity	: mm^2/s
ηv =	Volumetric efficiency	
ηm =	Mechanical efficiency	
ηt =	Total efficiency	
k =	Resistance figure	
V_{ac} =	Accumulator size	
V_x	Required oil capacity available in accumulator	
P_1 =	Lowest oil pressure	
P_2 =	Highest oil pressure	
P_0 =	Pre-charge	

Ratio factors

Ratio factors

Power	1 kw	1.36 PS
	1 PS	75 kpm/s
		0.736 kw

Symbols and Tables

Ratio factors (continued)

Torque	1 kpm	9.81 Nm
		7.233 lbf ft
	1 Nm	0.102 kpm
Pressure	1 kp/cm^2	98.000 Pa
		0.981 bar
		9.81 N/cm^2
		14.22 psi
	1 psi	0.06895 bar
		0.0703 kp/cm^2
	1 bar	1.0194 kp/cm^2
Volume	1 US gallon	3.785 liter
	1 Eng. gallon	4.546 liter
	1 in^3	16.38 cm^3
	1 liter	1.0 dm3
Area	1 in^2	645.2 mm^2
	1 fuss^2	92900 mm^2
Speed	1 km/h	0.2778 m/s
	1 fuss/s	0.3048 m/s
	1 mile/h	0.447 m/s
Acceleration	1 fuss/s^2	0.3048 m/s^2
Length	1 in	25.4 mm
	1 fuss	0.3048 m
	1 yd	0.9144 m

Pump

Power consumption $N_{an} = \frac{Q \times P}{600 \times \eta t}$ [kW]

Supplied oil capacity $Q = \frac{q \times n \times \eta v}{1000}$ [l/min]

Input torque $M = \frac{q \times P}{1000 \times \eta m}$ [Nm]

Motor

Oil consumption $Q = \frac{q \times n}{1000 \times \eta v}$ [l/min]

Output torque $M = \frac{q \times \Delta P \times \eta m}{62.8}$ [Nm]

Output power $N = \frac{Q \times \Delta P \times \eta t}{600}$ [kW]

Speed $n = \frac{Q \times \eta P \times 1000}{q}$ [min^1]

Symbols and Tables

Cylinder

Compressive force $F = P \times A \times \eta m$ [daN]

Tensile force $F = P \times a \times \eta m$ [daN]

Speed out $v = \dfrac{Q \times \eta v}{6 \times A}$ [m/s]

Speed in $v = \dfrac{Q \times \eta v}{6 \times a}$ [kW]

Oil consumption out $Q = A \times v \times 6$ [l/min]

Oil consumption in $Q = a \times v \times 6$ [l/min]

Compressive force with differential cut-in $F = P\,(A - a)\,\eta m$ [daN]

Tube

Flow speed $v = \dfrac{Q \times 100}{6 \times D^2 \times 0.785}$ [m/s]

Pressure loads in straight pipe leads $= \dfrac{\lambda \times L \times 0.89 \times v^2 \times 5}{Di}$ [bar]

Resistance number: λ lam $= \dfrac{64}{R_e}$ λ turb. $= \dfrac{0.316}{4\sqrt{R_e}}$

Reynolds number $R_e = \dfrac{v \times Dh \times 1000}{\upsilon}$

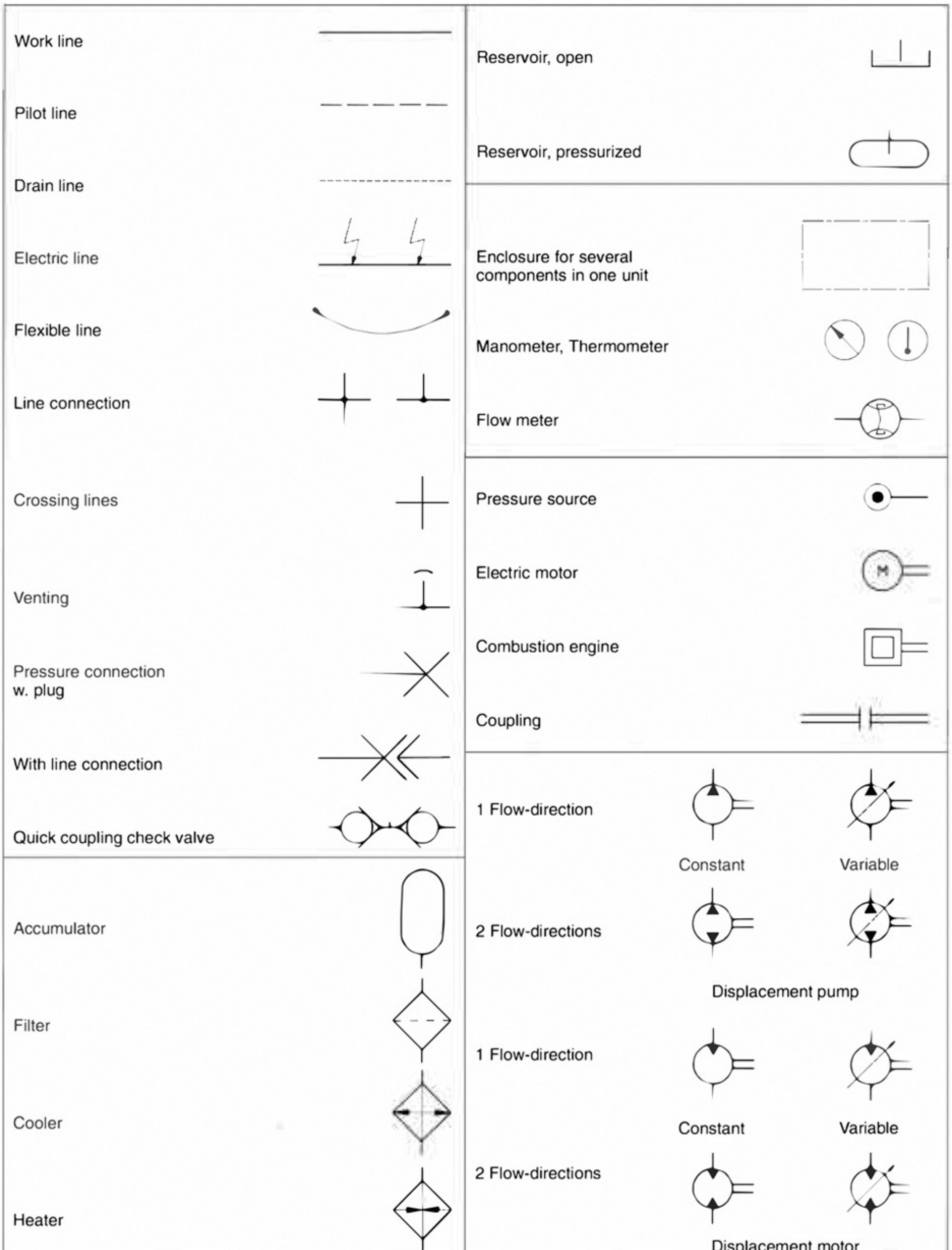
Accumulator size

With slow charging and slow discharging $V_{ac} = \dfrac{V_x \times \dfrac{P_1}{P_0}}{1 - \dfrac{P_1}{P_2}}$

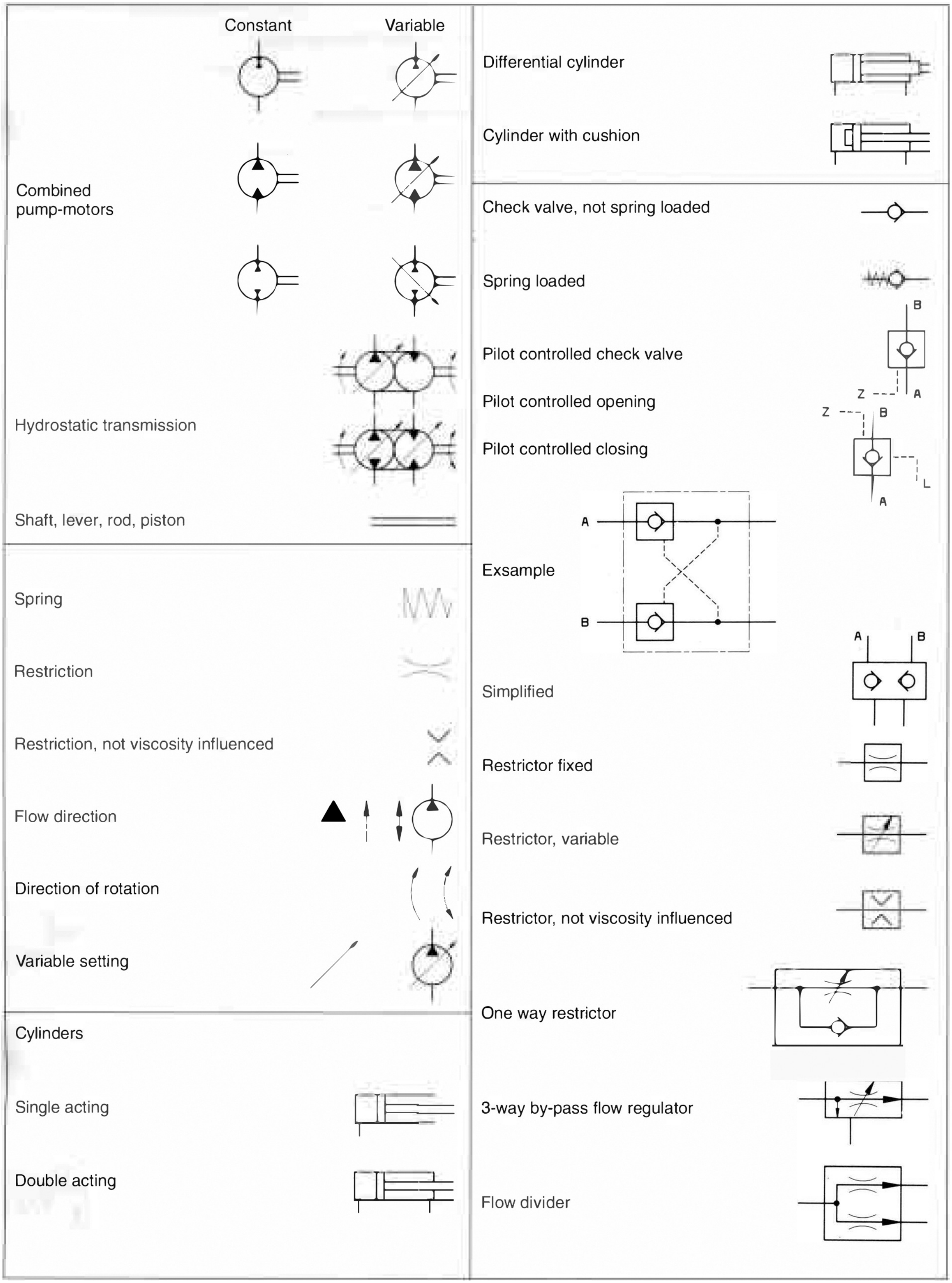
With quick charging and quick discharging $V_{ac} = \dfrac{V_x \times \dfrac{P_1}{P_0}}{1 - \left(\dfrac{P_1}{P_2}\right)^{\frac{1}{1.5}}}$

With slow charging and quick discharging $V_{ac} = \dfrac{V_x \times \dfrac{P_2}{P_0}}{\left(\dfrac{P_2}{P_1}\right)^{\frac{1}{1.5}} - 1}$

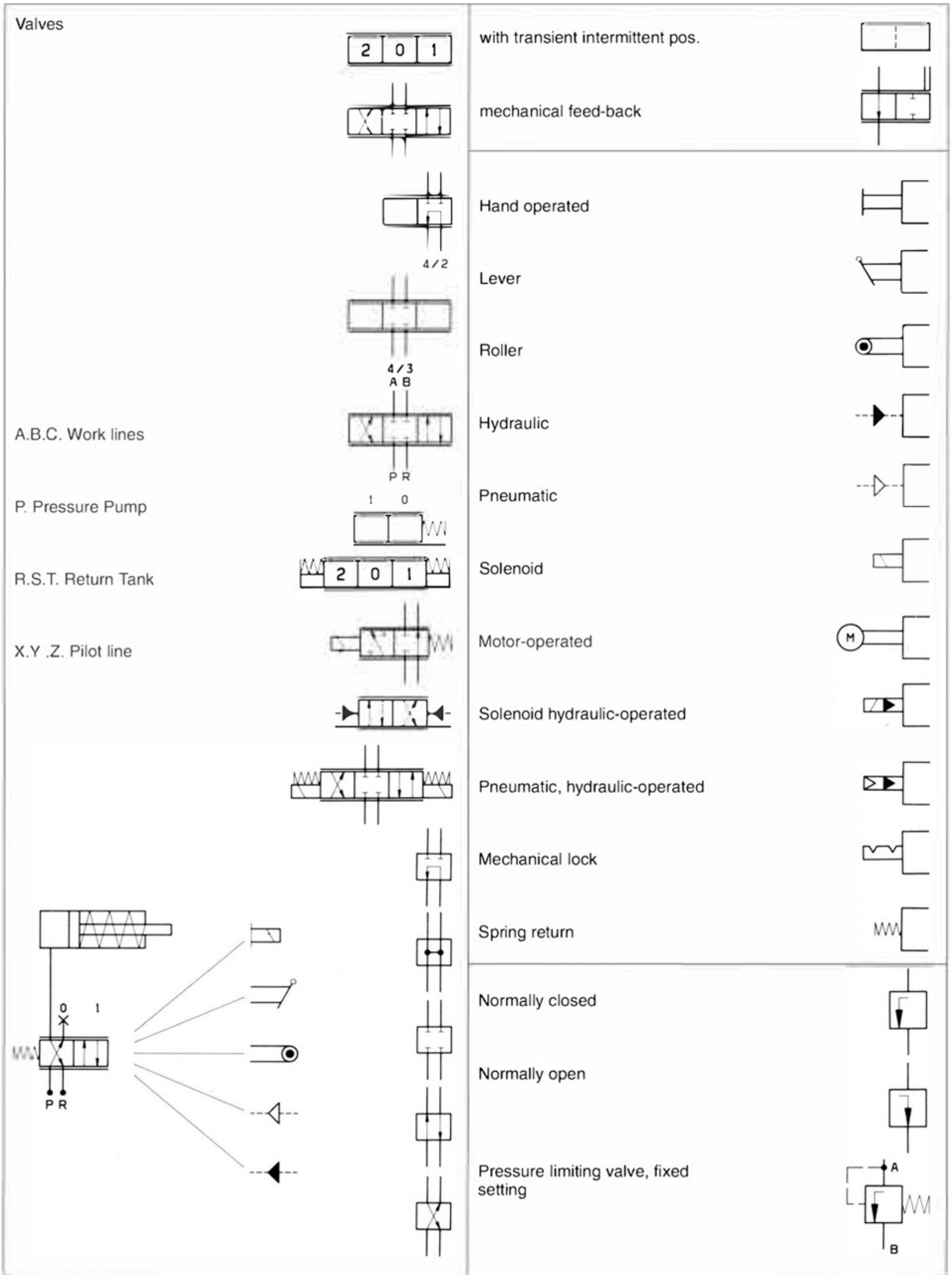
ISO/CETOP Symbols



ISO/CETOP Symbols

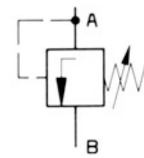


ISO/CETOP Symbols

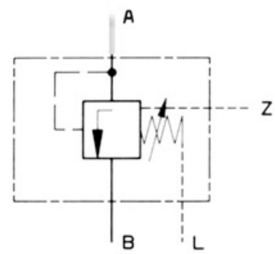


ISO/CETOP Symbols

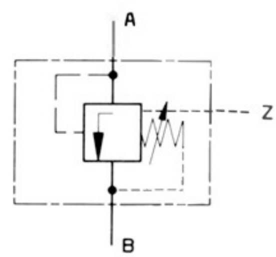
Pressure limiting valve, variable



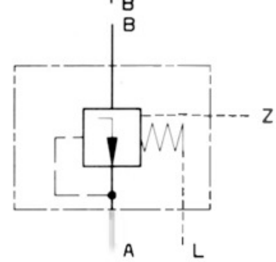
Pilot operated, external drain line



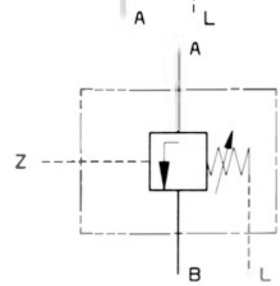
Internal drain



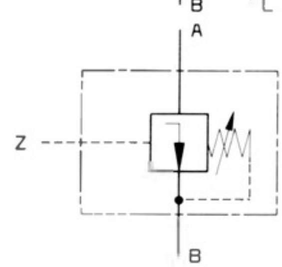
Pressure reduction valve



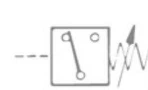
Pilot controlled opening valve



Pilot controlled closing valve



Pressure switch



Catalogues or leaflets available

Hydraulic components leaflets or catalogues

- Low speed hydraulic motors
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