6

Hydraulic and pneumatic accessories

Hydraulic reservoirs

A hydraulic system is closed, and the oil used is stored in a tank or reservoir to which it is returned after use. Although probably the most mundane part of the system, the design and maintenance of the reservoir is of paramount importance for reliable operation. Figure 6.1 shows details of a typical reservoir.

The volume of fluid in a tank varies according to temperature and the state of the actuators in the system, being minimum at low tem-

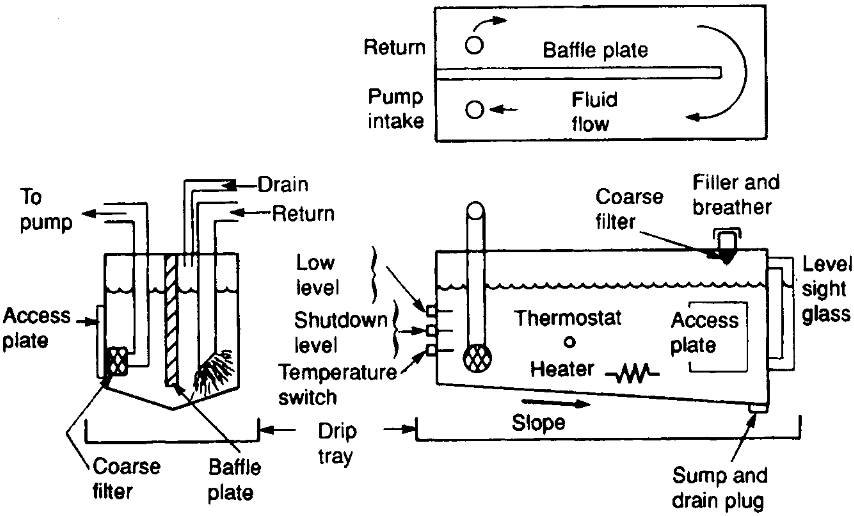


Figure 6.1 *Construction of a hydraulic reservoir*

perature with all cylinders extended, and maximum at high temperature with all cylinders retracted. Normally the tank volume is set at the larger of four times the pump draw per minute or twice the external system volume. A substantial space must be provided above the fluid surface to allow for expansion and to prevent any froth on the surface from spilling out.

The tank also serves as a heat exchanger, allowing fluid heat to be removed. To obtain maximum cooling, fluid is forced to follow the walls of the tank, from the return line to pump suction inlet, by a baffle plate down the tank centre line. This plate also encourages any contamination to fall to the tank bottom before reaching the pump inlet, and allows any entrapped air to escape to the surface. The main return line should enter from the top of the tank to preclude the need for a check valve and end below the minimum tank level to prevent air being drawn into the oil. The return flow should emerge into the tank through a diffuser with a low velocity of around 0.3 m/sec to prevent disturbance of any deposits at the base of the tank. The flow should be directed at the tank wall to assist cooling.

If, as is commonly the case, the external components outside the tank are below the oil level in the tank the return line should be equipped with a removable anti-siphonage plug. This should be removed to allow air into the return line before any external components are disconnected. Without this precaution a siphon backflow can occur which is very difficult to stop. If you have never encountered it before the sudden and apparently unstoppable flow of oil from the return pipe on disconnection can be very surprising.

Low pressure returns (such as drains from motors or valves) must be returned above fluid level to prevent back pressure and formation of hydraulic locks.

Fluid level is critical. If it is too low, a whirlpool forms above the pump inlet, resulting in air being drawn into the pump. This air results in maloperation, and will probably result in pump damage.

A level sight glass is essential to allow maintenance checks to be carried out. The only route for oil to leave a hydraulic system is, of course, by leaks so the cause of any gross loss of fluid needs investigation. In all bar the smallest and simplest systems, two electrical float switches are generally included giving a remote (low level) warning indication and a last ditch (very low level) signal which leads to automatic shutdown of the pump before damage can occur.

The temperature of fluid in the tank also needs monitoring and as an absolute minimum a simple visual thermometer should be included. The ideal temperature range is around 45 to 50°C and, usually, the problem is keeping the temperature down to this level. Ideally an electrical over-temperature switch is used to warn the user when oil temperature is too high.

When the system is used intermittently, or started up from cold, oil temperature can be too low, leading to sluggish operation and premature wear. A low temperature thermostat and electrical heater may be included to keep the oil at an optimum temperature when the system is not in use.

Reservoirs are designed to act as collecting points for all the dirt particles and contamination in the system and are generally constructed with a V-shaped cross section forming a sump. A slight slope ensures contamination collects at the lower end where a drain plug is situated. Often magnetic drain plugs are used to trap metallic particles.

Reservoirs should be drained periodically for cleaning, and a removable man access plate is included for this purpose. This is *not* the most attractive of jobs!

Oil is added through a filler cap in the tank top. This doubles as a breather allowing air into and out of the tank as the volume of fluid changes. A coarse filter below the breather prevents contamination entering the tank as fluid is added.

Tank air filters are commonly forgotten in routine maintenance. The oil in a typical tank changes considerably during operation as temperatures change and actuators operate. This change in volume is directly reflected in air changes both in and out of the tank. The only route for this air flow is through the filters. If these become blocked the tank may become pressurised and fail disastrously.

Reservoirs are generally constructed from welded steel plate with thin side walls to encourage heat loss. The inside of the tank is shot blasted then treated with protective paint to prevent formation of rust particles.

At some time in the life of a hydraulic system there will eventually be oil spillage around the tank, whether from leakage, over-enthusiastic filling or careless maintenance. It is therefore good practice to put substantial drip trays under reservoir pumps and associated valves to limit oil spread when the inevitable mishaps occur.

Hydraulic accumulators

In a simple hydraulic system, the pump size (delivery rate and hence motor power) is determined by the maximum requirements of the actuators. In Figure 6.2 a system operates intermittently at a

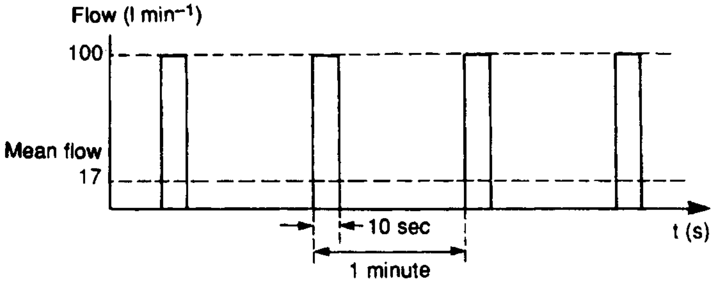


Figure 6.2 *A simple system with uneven demands. To supply this without an accumulator a 100 l min^{-1} is required although the mean flow is only 17 1/min*

pressure of between 150 and 200 bar, needing a flow rate of 100 l min^{-1} for 10 s at a repetition rate of 1 minute. With a simple system (pump, pressure regulator and loading valve) this requires a 200 bar, 100 l min^{-1} pump (driven by about a 50 hp motor) which spends around 85% of its time unloading to tank.

In Figure 6.3a a storage device called an accumulator has been added to the system. This can store, and release, a quantity of fluid at the required system pressure. In many respects it resembles the operation of a capacitor in an electronic power supply.

The operation is shown in Figure 6.3b. At time A the system is turned on, and the pump loads causing pressure to rise as the fluid is delivered to the accumulator via the non-return valve V_3. At time B, working pressure is reached and a pressure switch on the accumulator causes the pump to unload. This state is maintained as non-return valve V_3 holds the system pressure.

The actuator operates between times C and D. This draws fluid from the accumulator causing a fall of system pressure. The pressure switch on the accumulator puts the pump on load again but it takes until time E before the accumulator is charged ready for the next actuator movement at time F.

An accumulator reduces pump requirements. The original system required a 100 l min^{-1} pump. With an accumulator, however, a pump only needs to provide 17 l min^{-1} (that is, 100 l min^{-1} for 10 secs every minute). Pump size, and hence motor size, have been reduced by a factor of six with obvious cost and space savings, plus gains in ancillary equipment such as motor starters and cabling. There is no gain in the energy used; with the simple system a 50 hp motor loads for 17% of the time, with an accumulator a 10 hp motor loads for about 90% of the time.

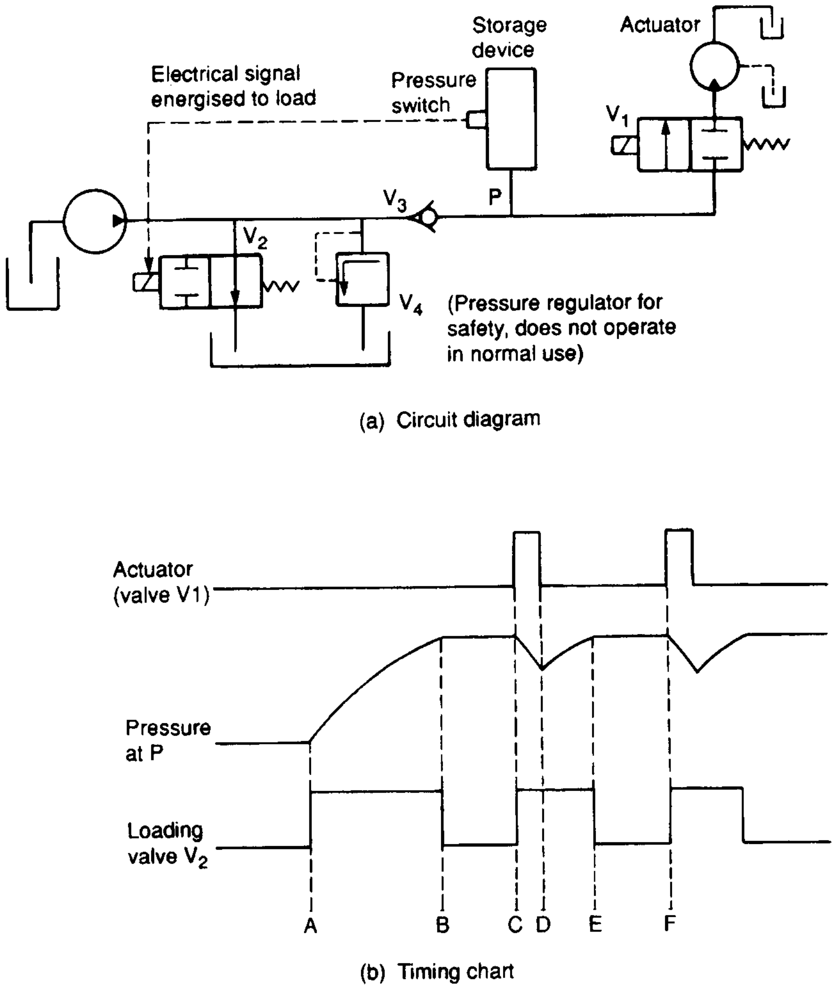


Figure 6.3 *System with an accumulator*

Most accumulators operate by compressing a gas (although older and smaller accumulators may work by compressing a spring or lifting a weight with a cylinder). The most common form is the gas-filled bladder accumulator shown in Figure 6.4. Gas is precharged to some pressure with the accumulator empty of fluid when the whole of the accumulator is filled with gas. A poppet valve at the accumulator base prevents the bladder extruding out into the piping.

Accumulators are sized by Boyle's law and a knowledge of the demands of the actuators. For the example system of Figure 6.2,

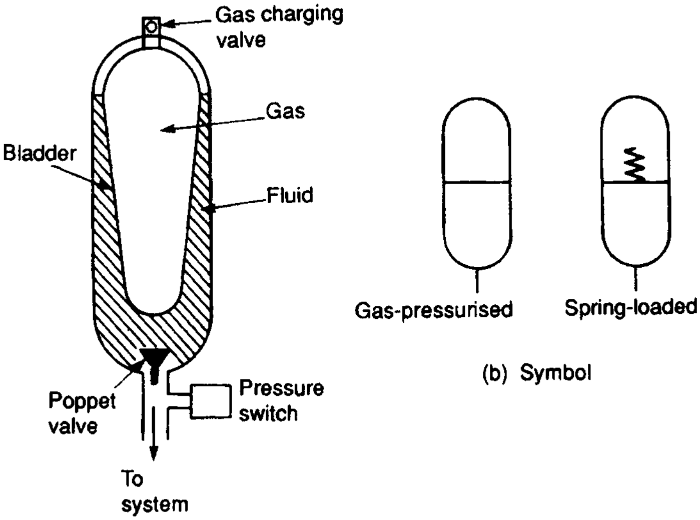


Figure 6.4 *The accumulator*

assuming a precharge of 120 bar, a charged accumulator pressure of 180 bar and a fall to a pressure to 160 bar during the removal of 17 litres of fluid: let V be volume of accumulator. This gives us the three states illustrated in Figure 6.5 to which Boyle's law can be applied to find the required accumulator volume.

From Figure 6.5b and c using Boyle's law:

$$160v = 180(v - 17)$$

which reduces to:

$$v = 153 \text{ litres}$$

From Figure 6.5a:

$$120V = 160 \times 153$$

or:

$$V = 204 \text{ litres}$$

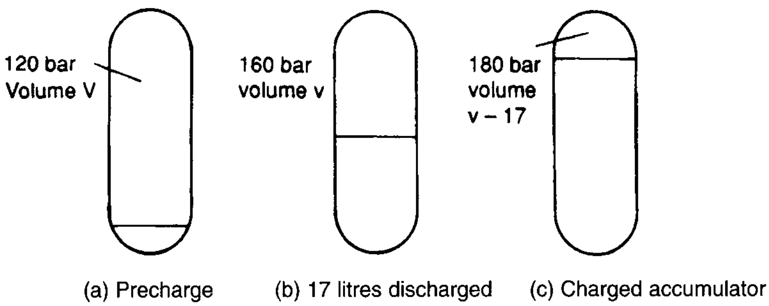


Figure 6.5 *Sizing an accumulator*

Hence an accumulator of around 250 litres is required, with a precharge of 120 bar and a pressure switch set at 180 bar.

Accumulators can also be used to act as 'buffers' on a system to absorb shocks and snub pressure spikes. Again the accumulator acts in similar manner to a capacitor in an electronic circuit.

An accumulator, however, brings an additional danger into the system, as it is possible for high pressures to exist in the circuit even though the pump has been stopped. If a coupling is opened under these circumstances the accumulator discharges all its fluid at working pressure. The author speaks from personal experience of having committed this cardinal sin and being covered in oil for his mistake!

Extreme care should therefore be taken when working on circuits with accumulators. Normally a manual or automatic blowdown valve is included to allow the accumulator pressure to be released. The pressure gauge should be observed during blowdown and no work undertaken until it is certain all pressure has been released. Figure 6.6 shows typical blowdown circuits.

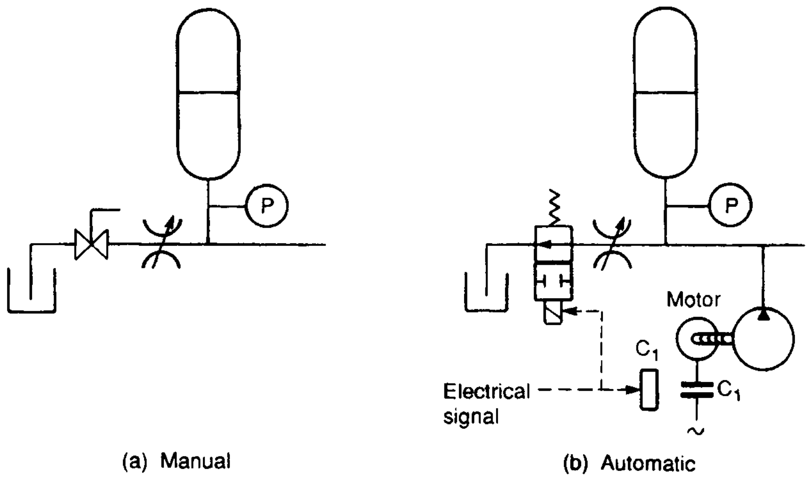


Figure 6.6 *Accumulator blowdown circuits. In each case flow from the accumulator is restricted to prevent an explosive decompression*

Once a system has warmed up, a quick check can be made on the state of an accumulator with the flat of the hand. There should always be a significant temperature difference between the gas and the hydraulic oil and the oil/gas split can be detected by the temperature change on the body of the accumulator. If the whole body is the same temperature something has gone severely wrong with the gas bladder.

An accumulator is a pressurised vessel and as such requires certification if it contains more than 250 bar.litres. It will require a recorded expert visual inspection every five years and a full volumetric pressure test every ten years.

Hydraulic coolers and heat exchangers

Despite the occasional use of heaters mentioned earlier, the problem with oil temperature is usually keeping it *down* to the required 50°C. In small systems. the heat lost through reservoir walls is sufficient to keep the oil cool, but in larger systems additional cooling is needed. Table 6.1 shows typical heat losses from various sizes of reservoirs. It should be noted that the relationship between volume and heat loss (surface area) is non-linear, because surface area increases as the square of the linear dimensions, whereas volume increases as the cube.

Table 6.1 Heat loss for various tank volumes. These are only approximate as few tanks are pure cubes

Vol (l)	L (m)	Surface area (m^2)	Heat loss (kW)
250	0.63	1.98	0.5
500	0.8	3.2	1.0
1,000	1.0	5.0	1.5
2,000	1.25	7.8	2.5
10,000	2.15	23.1	15.0

Based on cube tank where
$L^3 = v$

Surface area = $5 \times L^2$ (to allow for air gap at top and poor heat transfer from base)

Heat loss approx 0.3 kW m^{-2}

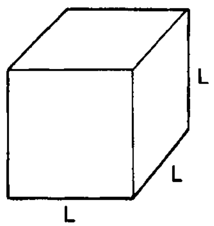


Figure 6.7 shows two types of cooler and their symbols. Water cooling is most common and Figure 6.7a shows the usual form of a shell and tube heat exchanger which is fitted in the return line to the tank. Note that the cooling water flows in the opposite direction to

the oil (giving rise to the term: counter-flow cooler). If the system is open to atmosphere and liable to stand unused in cold weather, protection must be included to prevent frost damage which can result in water-contaminated oil.

Air cooling is also common, shown in Figure 6.7b, with fans blowing air through a radiator matrix similar to those in motor cars (but, obviously, with a far higher pressure rating). Air cooling is noisy and occupies more space than a water cooler, but does not have the danger of contamination from leaks inside a water cooler.

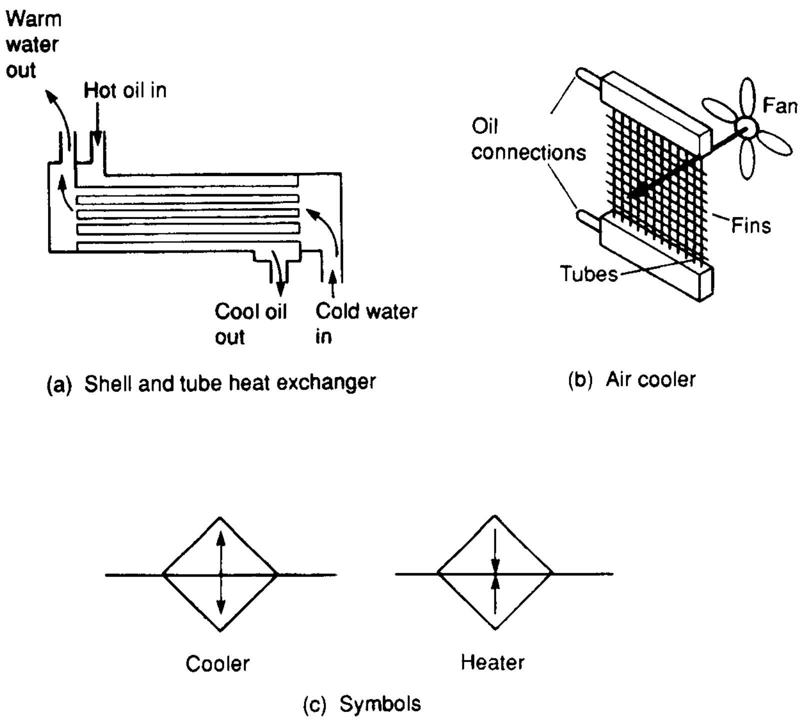


Figure 6.7 *Coolers and heat exchangers*

Hydraulic fluids

The liquid in a hydraulic system is used to convey energy and produce the required force at the actuators. Very early systems used water (in fact the name hydraulic implies water) but water has many disadvantages, the most obvious of which are its relatively high freezing point of 0°C, its expansion when freezing, its corrosive (rust formation) properties and poor lubrication. Modern fluids designed specifically for hydraulic circuits have therefore been developed.

The fluid conveys power in a hydraulic circuit, but it must also have other properties. Chapter 5 described the seals found in actuators. Moving parts in valves do not have seals; instead they rely on fine machining of spools and body to form the seal in conjunction with the fluid. Despite fine machining, irregularities still occur on the surface, shown in exaggerated form on Figure 6.8a. The fluid is required to pass between the two surfaces, holding them apart as Figure 6.8b, to reduce friction and prevent metal-to-metal contact which causes premature wear. Sealing and lubrication are therefore two important properties of hydraulic fluid.

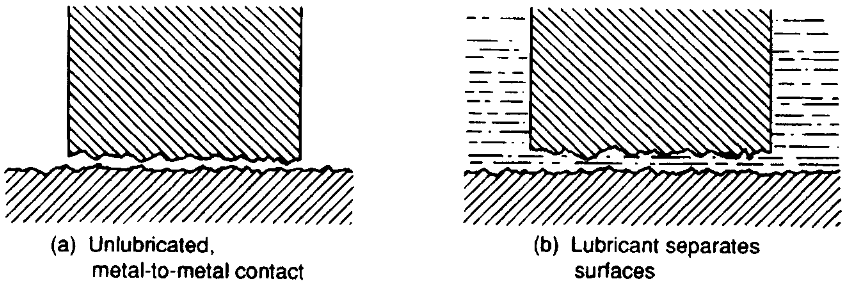


Figure 6.8 *Need for lubrication from hydraulic fluid*

The temperature of hydraulic fluid tends to rise with the work done, an ideal operating temperature being around 50°C (a useful quick check is to touch pipes in a system: the hand can be left indefinitely on metal at 40°C; can touch metal at 50°C but long contact is distinctly uncomfortable; but cannot be left for more than a second or so on metal at 60°C. If you cannot touch the pipes, the oil is too hot!). The fluid must be able to convey heat from where it is generated (valves, actuators, frictional losses in pipes) and must not be affected itself by temperature changes.

The fluid can cause deterioration of components. An extreme case is water causing rust, but less obvious reactions occur. A water-glycol fluid, for example, attacks zinc, magnesium and cadmium – all fairly common materials. Some synthetic fluids interact with nitrile and neoprene, and special paint is needed on the inside of the reservoir with some fluids. The fluid must therefore be chosen to be compatible with the rest of the system.

The fluid itself comes under attack from oxygen in air. Oxidation of fluid (usually based on carbon and hydrogen molecules) leads to deleterious changes in characteristics and the formation of sludge or gum at low velocity points in the system. The resulting oxidation products are acidic in nature, leading to corrosion. The fluid of course must be chemically stable and not suffer from oxidation. The temperature of fluid strongly influences the rate of oxidation; which rises rapidly with increasing temperature.

The most common hydraulic fluid is petroleum based oil (similar to car engine oil) with additions to improve lubrication, reduce foaming and inhibit rust. With the correct additives it meets all the requirements and does not react adversely with any common materials.

Its one major disadvantage is flammability; petroleum oils readily ignite. Although few (if any) hydraulic systems operate at temperatures that could ignite the oil, a major leak *could* bring spilt oil into contact with an ignition source. The probability of leakage needs consideration if petroleum oils are to be used.

If safety dictates that a fire resistant fluid is required, an oil and water emulsion is commonly used (such fluids are also attractive on the grounds of cost). The most common form is a water-in-oil emulsion (roughly 40% water, 60% oil). Oil-in-water emulsions are sometimes used, but their lubricating properties are poor. Both types of mixture have a tendency to form rust and to foam, but these characteristics can be overcome by suitable additions. Both types also need regular checking to ensure the correct oil/water ratio is being maintained.

Another non-flammable fluid is a water/glycol mix. This consists of roughly equal proportions of water and glycol (similar to car antifreeze) plus additions to improve viscosity (see below), inhibit foaming and prevent rust to which water-based fluids are vulnerable. Glycol-based fluids interact with many common materials, so the system components must be carefully chosen.

High water content fluids (HWCF) use 95% water with 5% additives making them totally non-flammable. They are often called 95/5 micro emulsion. Their use needs some care as they have very low viscosity, for all practical purposes the same as water, making applications using them prone to leaks at joints and seals. Unlike normal fluids external leaks can be difficult to see as at the normal 40–50°C operating temperature the fluid evaporates away without leaving any trace.

Spool valves have an inherent leakage and this can be problematical with low viscosity fluids such as HWCF. Cartridge valves, described in Chapter 4, are therefore often used with HWCF.

The high water content makes precautions against rust very important. Any 95/5 components removed from service must be protected against exposure to air. Some manufacturers will not honour their warranties when 95/5 fluid has been used.

Synthetic fluids based on chemicals such as phosphate esters are also non-flammable and can be used at very high temperatures. These tend to have high densities, which limit the height allowed between tank and pump inlet without cavitation occurring, and do not operate well at low temperatures. Systems with synthetic fluids usually require heaters in the tank to preheat fluid to operating temperature. Synthetic fluids are the most expensive form of hydraulic oil.

The properties of a liquid are largely determined by its resistance to flow, which is termed its viscosity. In non-scientific terms we talk about treacle having high viscosity, and water having low viscosity. Both extremes bring problems; a low viscosity fluid flows easily and wastes little energy, but increases losses from leakage. A viscous fluid seals well, but is sluggish and leads to energy and pressure losses around the system. Hydraulic fluid has to hit a happy medium between these extremes, so some way of defining viscosity is required.

There are basically two techniques of specifying viscosity. The absolute scientific method measures the shear force between two plates separated by a thin fluid film, shown as Figure 6.9. The most common unit is the poise (a cgs unit) which is the measure of shear force in dynes, for surface areas of 1 cm^2 separated by 1 cm of fluid. The centipoise (0.01 poise) is a more practical unit. Kinematic viscosity, defined with a unit called the stokes, is given by the absolute viscosity (in poise) divided by the density (in gm cm^{-3}).

A practical unit is the centi-stokes; a typical hydraulic fluid will have a viscosity of around 40 centi-stokes and low viscosity fluid such as HWCF about 1 centi-stoke. Not surprisingly this much lower viscosity means HWCF is very prone to leaks.

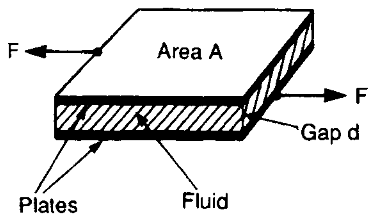


Figure 6.9 *Scientific definition of viscosity in terms of shear force*

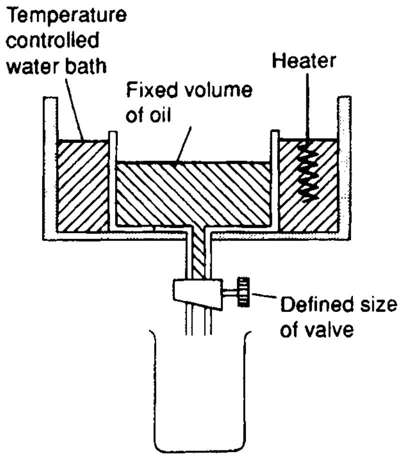


Figure 6.10 *Practical definition of viscosity*

The poise and the stokes are units denoting scientific definitions of viscosity. In hydraulics, all that is really needed is a relative comparison between different liquids. This is achieved with the practical experiment shown in Figure 6.10, where a fixed volume of oil is heated to a test temperature then allowed to drain out through a fixed-sized valve. The time taken to drain in seconds is a measure of the viscosity (being high for high viscosity liquids and low for low viscosity liquids).

The test of Figure 6.10 (generally performed at 100°F and 210°F with a volume of 60 cm^3) gives viscosity in saybolt universal seconds (SUS). The Fahrenheit basis of these definitions come from the American origin. Hydraulic fluid normally has a viscosity between 150 and 250 SUS defined at 100°F, although higher values are used in high temperature applications.

Viscosity can also be given by similar tests for engine oils devised by the American Society of Automotive Engineers (SAE). These give Winter numbers with suffix W (e.g., 10W, 20W) defined at 0°F, and Summer numbers defined at 210°F. An oil rating of 10W SAE, for example, covers the range 6,000 to 12,000 SUS at 0°F, while 30SAE covers the range 58 to 70 SUS at 210°F.

Viscosity decreases with increasing temperature, and this is given in SAE units in the form SAE 10W50, for example. This variation in viscosity with temperature is defined by the viscosity index, a unit based on an arbitrary scale from zero (poor, large variation in viscosity with temperature) to 100 (good, small variation with temperature). The range zero to 100 was chosen to relate to standards obtainable with practical fluids rather than some absolute measurable standard. Most hydraulic oils have a viscosity index of about 90.

The reliability of a hydraulic system is strongly influenced by the state of fluid. Contamination from dirt or the products of oxidation and deterioration of a fluid's lubrication ability will lead to rapid wear and failure.

Pneumatic piping, hoses and connections

The various end devices in a pneumatic system are linked to the air receiver by pipes, tubes or hoses. In many schemes the air supply is installed as a fixed service similar, in principle, to an electrical ring main allowing future devices to be added as required. Generally, distribution is arranged as a manifold (as Figure 6.11a) or as a ring main (as Figure 6.11b). With strategically placed isolation valves, a ring main has the advantage that parts of the ring can be isolated for maintenance, modification or repair without affecting the rest of the system.

Pneumatic systems are vulnerable to moisture and, to provide drainage, the piping should be installed with a slope of about 1% (1 in 100) down from the reservoir. A water trap fitted at the lowest point of the system allows condensation to be run off, and all tap-offs are taken from the top of the pipe (Figure 6.11c) to prevent water collecting in branch lines.

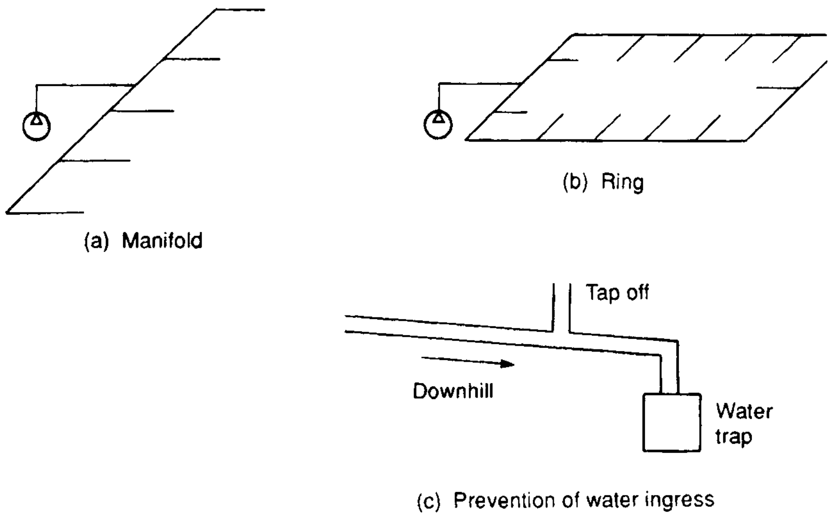


Figure 6.11 *Pneumatic piping*

The pipe sizing should be chosen to keep the pressure reasonably constant over the whole system. The pressure drop is dependent on maximum flow, working pressure, length of line, fittings in the line (e.g., elbows, T-pieces, valves) and the allowable pressure drop. The aim should be to keep air flow non-turbulent (laminar or streamline flow). Pipe suppliers provide tables or nomographs linking pressure drops to pipe length and different pipe diameters. Pipe fittings are generally specified in terms of an equivalent length of standard pipe (a 90 mm elbow, for example, is equivalent in terms of pressure drop to 1 metre of 90 mm pipe). If an intermittent large load causes local pressure drops, installation of an additional air receiver by the load can reduce its effect on the rest of the system. The local receiver is serving a similar role to a smoothing capacitor in an electronic power supply, or an accumulator in a hydraulic circuit.

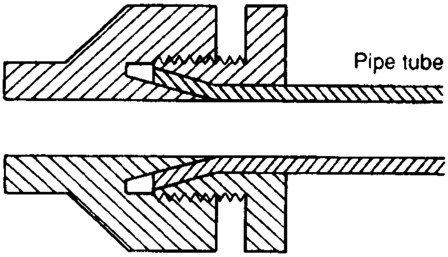
If a pneumatic system is installed as a plant service (rather than for a specific well-defined purpose) pipe sizing should always be chosen conservatively to allow for future developments. Doubling a pipe diameter gives four times the cross-sectional area, and pressure drops lowered by a factor of at least ten. Retrofitting larger size piping is far more expensive than installing original piping with substantial allowance for growth.

Black steel piping is primarily used for main pipe runs, with elbow connections where bends are needed (piping, unlike tubing, cannot be bent). Tubing, manufactured to a better finish and more accurate inside and outside diameters from drawn or extruded flexible metals such as brass, copper or aluminium, is used for smaller diameter lines. As a very rough rule, tubing is used below 25 mm and piping above 50 mm – diameters in between are determined by the application. A main advantage of tubing is that swept angles and corners can be formed with bending machines to give simpler and leak-free installations, and minimising the pressure drops associated with fittings.

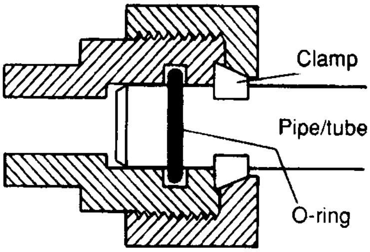
Connections can be made by welding, threaded connections, flanges or compression tube connectors. (Examples of compression fittings are illustrated in Figure 6.12.)

Welded connections are leak-free and robust, and are the prime choice for fixed main distribution pipe lines. Welding does, however, cause scale to be deposited inside the pipe which must be removed before use.

Threaded pipe connections must obviously have male threads on the pipes, and are available to a variety of standards, some of which



(a) Flanged connector



(b) O-ring

Figure 6.12 *Compression fittings*

are NPT (American National Pipe Threads), UNF (Unified Pipe Threads), BSP (British Standard Pipe Threads) and Metric Pipe Threads. The choice between these is determined by the standards already chosen for a user's site. Taper threads are cone shaped and form a seal between the male and female parts as they tighten, with assistance from a jointing compound or plastic tapes. Parallel threads are cheaper, but need an O-ring to provide the seal.

A pipe run can be subject to shock loads from pressure changes inside the pipe, and there can also be accidental outside impacts. Piping must therefore be securely mounted and protected where there is a danger from accidental damage. In-line fittings such as valves, filters and treatment units should have their own mounting and not rely on piping on either side for support.

At the relatively low pressure of pneumatic systems, (typically 5 to 10 bar), most common piping has a more than adequate safety margin. Pipe strength should, however, be checked – as a burst air line will scatter shrapnel-like fragments at high speed.

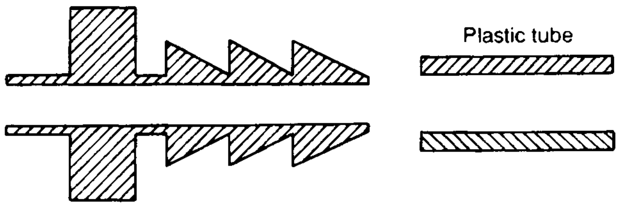


Figure 6.13 *Barbed connector for plastic tube*

Plastic tubing is used for low pressure (around 6 bar) lines where flexibility is needed. Plastic connections are usually made with barbed push-on connectors, illustrated in Figure 6.13.

Where flexibility is needed at higher pressure, hosing can be used. Pneumatic hoses are constructed with three concentric layers; an inner tube made of synthetic rubber surrounded by a reinforcement material such as metal braiding. A plastic outer layer is then used to protect the hosing from abrasion.

Hose fittings need care in use, as they must clamp tightly onto the hose, but not so tightly as to cut through the reinforcement. Quick-disconnect couplings are used where hoses are to be attached and disconnected without the need of shut-off valves. These contain a spring-loaded poppet which closes the outlet when the hose is removed. There is always a brief blast of air as the connection is made or broken, which can eject any dirt around the connector at high speed. Extreme care must therefore be taken when using quick-disconnect couplings.

Hydraulic piping, hosing and connections

The differences between hydraulic and pneumatic piping primarily arise from the far higher operating pressures in a hydraulic system.

Particular care has to be taken to check the pressure rating of pipes, tubing, hosing and fittings, specified as the bursting pressure. A safety factor is defined as:

$$\text{safety factor} = \frac{\text{bursting pressure}}{\text{working pressure}}$$

Up to 60 bar, a safety factor of eight should be used, between 60 and 150 bar a safety factor of six is recommended, while above 150 bar a safety factor of four is required. This may be compared with pneumatic systems where safety factors of around 40 are normally obtained with simple standard components.

The choice of piping or tubing is usually a direct consequence of pressure rating. These can be manufactured as welded, or drawn (seamless) pipe. Welded pipe has an inherent weakness down the welded seam, making seamless pipes or tubing the preferred choice for all but the lowest pressure hydraulic systems.

Hydraulic piping is specified by wall thickness (which determines the pressure rating) and outside diameter (OD, which determines the size of fittings to be used). It follows that for a given OD, a higher pressure pipe has a smaller inside diameter (ID). American piping is manufactured to American National Standards Institute (ANSI) specifications, which define 10 sets of wall thickness as a schedule number from 10 to 160. The higher the number, the higher the pressure rating. 'Standard' piping is schedule 40.

Pipes should be sized to give a specified flow velocity according to the expected flow. Typical flow velocities are 7–8 m/sec for a pressure line, and 3–4 m/sec for a return line. The lower velocity is specified for the return line to reduce the back pressure. For a similar reason the velocity in a pump suction line should be in the range 1.5–2 m/sec. At the point of exit from the return line diffuser into the tank the velocity should be very low, below 0.3 m/sec, to prevent stirring up any contamination at the base of the tank.

Like pneumatic piping, joints can be made by welding, with compression fittings (similar to those in Figure 6.12 but of higher pressure rating) or threaded connections and flanges. Particular care needs to be taken to avoid leaks at joints; in pneumatic systems a leak leads to loss of downstream pressure and perhaps an objectionable noise whereas a hydraulic leak loses expensive fluid and creates an oil-pool which is a fire and safety hazard.

Flexible hosing is constructed in several concentric layers, with the inner tubing being chosen to be compatible with the hydraulic fluid and its temperature. One (or more) braided reinforcing layers are used. At higher pressures the braiding will be wire. The outer layer is designed to resist abrasion and protect the inner layers. Hoses are generally manufactured complete with fittings. Hydraulic hoses, like pneumatic hoses, must be installed without twists (which can lead to failure at the fittings).

Quick-disconnect hydraulic connections are available, but the higher pressure, risk of spillage and danger of introducing dust into the system restricts their usage.