MEM18021B

Maintain Hydraulic Systems

Learner’s Guide
Copyright and Terms of Use

© Department of Training and Workforce Development 2016 (unless indicated otherwise, for example ‘Excluded Material’).

The copyright material published in this product is subject to the Copyright Act 1968 (Cth), and is owned by the Department of Training and Workforce Development or, where indicated, by a party other than the Department of Training and Workforce Development. The Department of Training and Workforce Development supports and encourages use of its material for all legitimate purposes.

Copyright material available on this website is licensed under a Creative Commons Attribution 4.0 (CC BY 4.0) license unless indicated otherwise (Excluded Material).

Except in relation to Excluded Material this license allows you to:

- Share — copy and redistribute the material in any medium or format
- Adapt — remix, transform, and build upon the material for any purpose, even commercially

provided you attribute the Department of Training and Workforce Development as the source of the copyright material. The Department of Training and Workforce Development requests attribution as: © Department of Training and Workforce Development (year of publication).

Excluded Material not available under a Creative Commons license:
1. The Department of Training and Workforce Development logo, other logos and trademark protected material; and
2. Material owned by third parties that has been reproduced with permission. Permission will need to be obtained from third parties to re-use their material.

Excluded Material may not be licensed under a CC BY license and can only be used in accordance with the specific terms of use attached to that material or where permitted by the Copyright Act 1968 (Cth). If you want to use such material in a manner that is not covered by those specific terms of use, you must request permission from the copyright owner of the material.

If you have any questions regarding use of material available in this product, please contact the Department of Training and Workforce Development.

Training Sector Services
Telephone: 08 6212 9789
Email: sectorcapability.ip@dtwd.wa.gov.au
Website: www.dtwd.wa.gov.au
Contents

Introduction........................................................................................................................................... 5

Recommended resources .................................................................................................................. 7

How to use this learner’s guide .......................................................................................................... 7

How you will be assessed .................................................................................................................... 7

Section 1 – Hydraulic safety and introduction to hydraulic systems .............................................. 9

Hydraulic safety .................................................................................................................................. 9

Introduction to hydraulic systems ..................................................................................................... 12

Section 2 – Hydraulic maintenance principles ................................................................................. 15

System maintenance ........................................................................................................................... 15

Fluid contamination and filtration ..................................................................................................... 16

The effects of contamination on hydraulic components ................................................................. 18

Maintenance suggestions .................................................................................................................... 22

Section 3 – Hydraulic system testing and diagnosis ........................................................................ 29

Introduction ........................................................................................................................................ 29

System testing procedures ............................................................................................................... 31

System testing methods ..................................................................................................................... 38

Hydraulic circuitry and components ................................................................................................. 45

Troubleshooting in hydraulic systems ............................................................................................... 58

Circuit reading .................................................................................................................................... 59

Fault-finding charts ............................................................................................................................ 71
Introduction

This resource is designed to help the student gain the knowledge and skills required to achieve the competency MEM18021B – Maintain Hydraulic Systems. This unit may be assessed on the job, off the job – or through a combination of the two. The skills covered by this unit can be demonstrated by an individual working alone or as part of a team. The unit comprises the four elements detailed in the table below.

<table>
<thead>
<tr>
<th>MEM18021B – Maintain Hydraulic Systems</th>
<th>Elements and performance criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element 1: Undertake preventative maintenance checks/adjustments on hydraulic systems</td>
<td>1.1 System components, assemblies or sub-assemblies are identified and prepared for inspection/preventative maintenance.</td>
</tr>
<tr>
<td></td>
<td>1.2 Visual inspection and testing with appropriate test equipment are carried out according to fluid power principles, procedures and safety requirements.</td>
</tr>
<tr>
<td></td>
<td>1.3 Scheduled preventive maintenance tasks are performed, including obvious repairs and adjustments, according to manufacturers’ specifications using fluid power techniques/practices.</td>
</tr>
<tr>
<td>Element 2: Undertake fault finding on hydraulic system</td>
<td>2.1 Designated hydraulic system components are identified and a visual inspection of the system is carried out.</td>
</tr>
<tr>
<td></td>
<td>2.2 System operator is consulted where appropriate and additional data is collected.</td>
</tr>
<tr>
<td></td>
<td>2.3 Maintenance reports and preventative maintenance schedules are checked and reviewed for additional fault-finding data.</td>
</tr>
<tr>
<td></td>
<td>2.4 Using fluid power principles, checks and tests are undertaken using appropriate test equipment and techniques.</td>
</tr>
<tr>
<td></td>
<td>2.5 Faults and malfunctions are identified and verified.</td>
</tr>
<tr>
<td></td>
<td>2.6 Faults and malfunctions are documented or reported by appropriate means to designated personnel and actioned.</td>
</tr>
</tbody>
</table>
### Element 3: Repair and/or rectify hydraulic system

| 3.1 | System or sub-assembly is isolated safely and residue pressure is discharged in accordance with prescribed procedure and checked for correct isolation. |
| 3.2 | Isolated system or sub-assembly is tagged according to designated means. |
| 3.3 | Components or sub-assembly is removed from system using correct removal principles and techniques. |
| 3.4 | Components or sub-assemblies are dismantled, examined and verified for replacement, overhaul or repair, using correct and appropriate techniques and procedures. |
| 3.5 | Replacement items are selected from manufacturers’ catalogues to meet specifications. |
| 3.6 | Faulty items are rectified using correct and appropriate principles, techniques and procedures. |
| 3.7 | Component or sub-assembly items are refitted to equipment and tested for correct operation against specifications. |

### Element 4: Recommission hydraulic system

| 4.1 | System or sub-assembly is recommissioned according to prescribed procedures and specifications. |
| 4.2 | Using fluid power principles and system application techniques, correct operation of the system is verified. |
| 4.3 | Appropriate follow-up procedures are instigated. |
| 4.4 | Maintenance records/service reports are updated and completed by appropriate designated means. |
Recommended resources


*Industrial Hydraulic Technology* 1992, video series, Trinity Workplace Learning, Chattanooga.

How to use this learner’s guide

This book is your guide to developing the underpinning knowledge and practical skills required to pass this unit of competency. It has been divided into three sections.

Section 1 must be completed first, as it covers hydraulic safety and basic hydraulic principles – on which you will be assessed in the practical activities. Each section has an introduction to the topic area and directs you to undertake tasks, such as reading a section of a reference text or watching a video, before you do the practical activity for that section. Each section also contains review questions. These are designed to allow you to check your understanding of the topic area before you start the practical activity. Your lecturer will question you to assess your underpinning knowledge during the practical assessments.

How you will be assessed

Due to the range of available hydraulic equipment and systems in industry, the practical tasks you will need to undertake to meet the outcomes for this competency will be determined by your assessor.

You must have a good understanding of the topic area before you attempt these tasks and you must adhere to the appropriate manuals and precautions. Adherence to safety procedures, correctness of maintenance procedures and underpinning knowledge will also be assessed during these tasks. These assessments can be performed either on or off the job. Your assessor must be a qualified workplace assessor.
Section 1 – Hydraulic safety and introduction to hydraulic systems

Hydraulic safety

Before attempting to perform any testing or checks on a system or dismantling any components, you should make sure that working conditions are safe. The following rules must be observed. They are essential for safety – and will be included in the assessment for this unit of competency.

1. Isolate the machine from external power supplies.
2. Use the 'tag system' to prevent other people from trying to operate the machine. This is extremely important – particularly if the machine may be left unattended. The types of tags most commonly used are illustrated below.

![Figure 1: danger tags](image)

(Reproduced with the permission of Industrial Foundation for Accident Prevention.)

3. Provide support for pressure-held loads that could fall when the pressure is removed through disconnection of the working unit.
4. Relieve the system pressure. It is dangerous to remove a hose that contains oil under pressure. Operate valves each way after the pump has been switched off and the system is at rest, to bleed it of any line pressures.

Note: Although oil under pressure does not contain any stored energy, as compressed air does, stored energy may be present in pressurised flexible hoses, in a cylinder holding up a load or in a charged accumulator.

5. Some hydraulic pumps and control valves are heavy – so you must provide a means of support, such as a chain hoist, floor jack or blocks, before removing them.
Section 1 – Hydraulic safety and introduction to hydraulic systems

Hydraulic safety

Before attempting to perform any testing or checks on a system or dismantling any components, you should make sure that working conditions are safe. The following rules must be observed. They are essential for safety – and will be included in the assessment for this unit of competency.

1. **Isolate** the machine from external power supplies.

2. Use the ‘tag system’ to prevent other people from trying to operate the machine. This is extremely important – particularly if the machine may be left unattended. The types of tags most commonly used are illustrated below.

![Danger tags](image)

*(Reproduced with the permission of Industrial Foundation for Accident Prevention.)*

3. Provide support for pressure-held loads that could fall when the pressure is removed through disconnection of the working unit.

4. Relieve the system pressure. It is dangerous to remove a hose that contains oil under pressure. Operate valves each way after the pump has been switched off and the system is at rest, to bleed it of any line pressures.

**Note:** Although oil under pressure does not contain any stored energy, as compressed air does, stored energy may be present in pressurised flexible hoses, in a cylinder holding up a load or in a charged accumulator.

5. Some hydraulic pumps and control valves are heavy – so you must provide a means of support, such as a chain hoist, floor jack or blocks, before removing them.
6. When working on machines with mobile parts, make sure there’s enough space in the workshop to conduct the maintenance procedure. For example, you must consider whether a rotating boom might collide with part of the workshop during machine testing – or whether some other activated device might hit the ceiling or overhead power lines.

7. Keep your work area tidy. Use drain trays under hydraulic equipment and, if any oil spillage occurs, clean it up immediately. Remember that one quality of oil is reduction of friction – and oil on the floor will reduce the friction between your footwear and the ground, which could lead to an accident.

8. Never service a hydraulic system while the motor, pump or actuators are operating – unless absolutely necessary.

9. To ensure control of the unit, keep the hydraulics in proper adjustment.

10. When washing parts, use a non-volatile cleaning solvent that is compatible with the hydraulic system.

11. When using test equipment coupled to flexible hoses, tie down the hoses and/or the equipment. As flexible hoses are pressurised, they stiffen and tend to straighten out. Unless restrained, any test equipment attached to the end will lift up in the air and then, when pressure is released, crash down again, potentially damaging itself.

12. Make sure that all line connections are tight and that lines are not damaged. Oil escaping under pressure is a fire hazard and can cause personal injury.

13. Be aware that, although manipulating hydraulic control valves may bleed down a system, pressure may still be trapped in a system which has counterbalance and pilot-operated check valves incorporated. This is because hydraulic pressure is required to operate these valves. You should therefore make yourself familiar with a system and its components before starting work on it.

14. Pinhole leaks in hydraulic hoses are a hazard and can be difficult to detect. Never use your hands to detect leaks, as oil can be injected into your bloodstream causing serious injury. When checking for pinhole leaks, a card or piece of cardboard should be used.
Activity 1 – Hydraulic safety

The following questions are designed to allow you to check your understanding of hydraulic safety before you apply it to your practical activities.

When you have completed the activity, check your answers with your lecturer or supervisor.

Question 1

List two things you must take into consideration when you are using a cleaning solvent on hydraulic components.

1. ___________________________________________________________________
2. ___________________________________________________________________

Question 2

What is the procedure for isolating a hydraulic machine before removing a component for servicing?

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

Question 3

State a recommended procedure to use when you are testing a hydraulic line for leaks.

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

Question 4

Explain why manipulating directional control valves may not necessarily bleed all the pressure in a hydraulic system.

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

_____________________________________________________________________
Introduction to hydraulic systems

This unit of competency provides theoretical and practical training for people responsible for the operation and maintenance of hydraulic equipment at trade level. Before proceeding through this learner’s guide, take note of the material below and complete the following activity.

The main components that make up a basic hydraulic system are:

- a power circuit, which consists of actuators (motors or cylinders) and their directional control valves, as well as fluid conductors and flow-control valves
- a reservoir
- pressure-control valves
- a pump and prime mover.

System comparison

Open-loop control systems

An open-loop system is a one-way system in which the control instructions are transmitted in one direction only, from the controller to the actuator via the control valve. There is no feedback loop from the actuator for checking that its movement complies with control instructions. The accuracy of the open-loop control system depends on the reliability of the equipment employed and the ‘external system disturbances’.
Closed-loop control systems

An automatic closed-loop system is one in which the controlled variable is continuously measured and compared with a command variable. The machine’s controlled action is adjusted according to any deviation or error signal generated. An error signal is generated when comparison shows a difference between the output position and the input control signal. This type of control is used in fluid power systems to operate servo-controlled hydraulic valves.

The closed-loop system illustrated below has a mechanical feedback. In this system, the body of the directional control valve (DCV) is mechanically linked to the actuator. Deflection of the lever will move the spool and allow fluid to move the actuator and hence the load. As the load moves, constant positional feedback is provided to the directional control valve.

Figure 2: closed-loop system
Activity 2 – Operation of basic hydraulic system

The following questions are designed to allow you to check your understanding of the operation of a basic hydraulic system.

Question 1
Name the four main components that make up a basic hydraulic system.

1. ___________________________________________________________________
2. ___________________________________________________________________
3. ___________________________________________________________________
4. ___________________________________________________________________

Question 2
Explain the function of each of the components listed in Question 1.

1. ___________________________________________________________________
2. ___________________________________________________________________
3. ___________________________________________________________________
4. ___________________________________________________________________

Question 3
Name the two major types of hydraulic system used in industry today.

1. ___________________________________________________________________
2. ___________________________________________________________________

Question 4
Explain the difference between the two types of system identified in Question 3.

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
Section 2 – Hydraulic maintenance principles

What you will accomplish in this section
This section of learning will provide you with underpinning knowledge necessary to enable you to:

- apply basic hydraulic principles
- prepare hydraulic systems or subsystems for maintenance
- apply hydraulic safety
- identify, inspect, repair, reassemble and test hydraulic systems and components to a given industrial configuration and specification
- identify and verify causes, faults and malfunctions in a system
- remove and test system/components
- correctly investigate and report on system faults.

System maintenance
A hydraulic system is easy to maintain, because the oil provides a very effective lubrication medium, while the system control valves protect the machine from mechanical overload.

Like any other mechanism, however, it must be operated and maintained correctly. Hydraulic systems can be damaged by excessive speeds and pressures, by fluid contamination and by high operating temperatures.

By using a regular maintenance program (preventative maintenance) to care for a hydraulic system, you can eliminate common problems and anticipate special ones. Problems can be corrected or averted before a breakdown occurs.

The following are the key problems that commonly need to be addressed in servicing hydraulic systems:

- contaminated oil
- poor fluid filtration
- incorrect fluid selection
- low fluid level
- high fluid temperature
- loose supply lines
- faulty seals.
The importance of cleanliness

Cleanliness is of supreme importance in servicing hydraulic systems. Keep dirt and other contaminants out of the system. Small particles can score valves, cause seizing of pumps and clog orifices – resulting in expensive repair jobs.

When servicing a hydraulic system, always make sure you do the following.

- Keep the oil clean.
- Keep the system clean.
- Keep your work area clean.
- Be careful when you change or add oil.

Strive to keep oil clean from the minute it is delivered to you. This entails a number of things. Choose a clean location for storing oil. When oil is taken out of storage, use only clean containers with lids for carrying it from storage to the point of use. Use a clean funnel fitted with a fine-mesh screen when pouring oil from the container into the reservoir.

Keep an adequate supply of clean strainers, funnels and oil containers. Store them in a clean, dust-free environment. Use a clean, lint-free cloth to wipe the dipstick when checking oil levels.

Ask machine operators and service technicians to do everything possible to prevent dirt getting into the oil during the operation and servicing of a machine.

Fluid contamination and filtration

Fluid contamination

Contamination of fluids is by far the greatest source of trouble in hydraulic systems. Contamination may occur in several ways – ranging from unsatisfactory storage and careless handling of fluid to ineffective filtration and inadequate cleaning of the system.

System cleanliness and filtration are important factors in the long-term performance and effectiveness of hydraulic oil. Removal of contaminants is beneficial to both its lubrication properties and working life, since foreign matter is likely to be abrasive and also to act as a catalyst in encouraging chemical degradation. Moreover, the performance of a system is upset when silting prevents valves from moving freely through their full travel.

Oil that's contaminated by fine, hard particles can lead to severe wear, both in narrow clearances and where sudden changes of direction occur. This problem is particularly serious where the essential sharp edges of control valves are rounded off by erosion in high rates of flow; the result is that fine working clearances (magnified in Figures 3–6) are widened to a degree that seriously affects the accuracy of control.

Effect of erosion

In modern hydraulic systems, the close tolerances and high precision of components make it essential to keep fluids as free as possible from contamination by dirt, deposits and other foreign matter. Freedom from trouble cannot be guaranteed, even when clean fluid straight from the supplier is put into a new system. Various internal sources can put foreign matter into circulation long after the system has been commissioned – matter such as pipe scale, rust, thread-sealing compound, casting sand, flakes of paint,
trapped swarf and weld spatter. Dirt and dust from the atmosphere may also be drawn into the system if the reservoir tanks are not properly fitted with filtered vents. Also, fine metal particles are continuously created by the normal wear of moving parts. Rust caused by water contamination can be a further source of trouble. Rusted parts do not operate smoothly and rust particles can score moving parts.

**Filtration**

Filtration is undoubtedly the most effective way of removing solid contaminants from hydraulic fluids and virtually all hydraulic systems today incorporate efficient filters. Ideally, a filtration unit should satisfy several requirements. It should:

- remove solid contaminants efficiently
- remove all particles larger than a critical size, determined by the characteristics of the system's hydraulic components
- be sited where it can be easily cleaned
- give some indication of loss of efficiency – for example, through a gauge which indicates when cleaning is required.

**Importance of oil and filter changes**

You can't get peak performance from a hydraulic system that isn't clean.

Whatever precautions you take when working with a hydraulic system, some contaminants will get into the system anyway. Good hydraulic oils will hold these contaminants in suspension and the filters will collect them as the oil passes through. Good hydraulic oil contains many additives which work to keep contaminants from damaging or plugging the system. However, these additives lose their effectiveness after a certain period or amount of use.

Therefore, you should change oil at the recommended intervals – to ensure you maintain an active oil.

A system's filters can absorb only a limited amount of dirt and other contaminants from the oil. Filters stop working once they reach their limit.

Before this point is reached, you should clean the filters or replace them with new ones so an active filtration process is maintained. Filters that have been removed should be inspected – the amount and type of contamination they have trapped will provide an insight to the health of the system.

*A filter is only as good as the maintenance it receives.*

**Filter service**

Frequency of cleaning is one of the most important considerations in utilising any filtration system – and maintenance staff need to adhere to strict cleaning schedules. Some filter units incorporate indicators that tell operators when the pressure drop across the element is approaching a level where cleaning or replacement is required.
The effects of contamination on hydraulic components

Hydraulic component manufacturers agree that dirt is the cause of most malfunctions and unsatisfactory component performance. The effects of dirt on the various components of hydraulic systems are discussed below.

**Pumps**

In hydraulic pumps, dirt can:
- destroy working tolerances within the pump
- cause vanes to stick, thereby creating erratic action
- cause vanes to wear out the cam ring
- wear out rotor slots
- increase shaft journal and bearing wear
- increase gear wear, resulting in inefficiency
- increase piston and cylinder wear, resulting in inefficiency.

Dirt in compensator controls on variable-volume pumps causes sticking, slow response and erratic delivery, which affects the performance of the entire system, resulting in excessive heat and inefficient power use.

**Relief valves**

Dirt in relief valves can cause:
- valve chatter
- seat wear within the valve
- valve failure, causing pressure to become erratic – which affects the function of the entire system.
The diagram below shows areas within a relief valve that are commonly affected by contamination.

Figure 3: compound relief valve – common contamination sites

Directional valves

Dirt contamination in directional control valves can cause:

- blocked orifices
- wear to spool and body lands, which creates excess internal leakage
- spools to stick, which can result in solenoid failure
- valves to stick and cause excessive shock loads with damage to hose, piping, fittings and various other components.

Figure 4: effects of contamination on directional control valves
Check valves
Check valves are designed to allow fluid flow in one direction. Dirt in these valves can:

- cause wear on the poppet seats, creating leakage
- permit fluid to bypass the check (reverse flow), as illustrated below.

![Check Valve Diagram](image)

*Figure 5: check valve malfunction*

Flow-control valves
In flow-control valves, dirt can cause erosion at the orifices, which will change the valve’s flow characteristics.

Servo valves
Servo valves require a high level of filtration to maintain their accuracy. Contamination in these valves can result in the erosion of sharp edges, which will affect metering. Dirt can also result in the blockage of nozzles, because of their very small size.

Cylinders
Contamination in linear actuators can result in:

- excessive wear of the cylinder rod, packing and bore
- malfunction of the cushions
- cylinder drift or creep
- the cylinder losing its capacity to hold a load.

Dirt in a hydraulic fluid:
- acts as a catalyst in breaking down molecular structure, causing gummy residual ‘varnish’
- attacks the oil additives and changes the composition of the fluid.

Proper maintenance of hydraulic systems should keep troubles to a minimum. Experience has shown that proper and efficient running of hydraulic equipment is almost entirely in the hands of the user. For example, an analysis of a manufacturer's call-outs to customers’ plants showed that 70 per cent of typical service calls were the result of improper condition of the oil concerned; dirty oil; incorrect oil type; water in the oil (rust); lacquer, varnish and sludge formation; or lint and/or other contaminants in the oil. Oil with good demulsification properties will not only resist mixing with water but allow rapid separation of oil and water mixtures.
Check valves

Check valves are designed to allow fluid flow in one direction. Dirt in these valves can:
- cause wear on the poppet seats, creating leakage
- permit fluid to bypass the check (reverse flow), as illustrated below.

![Figure 5: check valve malfunction](image)

Flow-control valves

In flow-control valves, dirt can cause erosion at the orifices, which will change the valve’s flow characteristics.

Servo valves

Servo valves require a high level of filtration to maintain their accuracy. Contamination in these valves can result in the erosion of sharp edges, which will affect metering. Dirt can also result in the blockage of nozzles, because of their very small size.

Cylinders

Contamination in linear actuators can result in:
- excessive wear of the cylinder rod, packing and bore
- malfunction of the cushions
- cylinder drift or creep
- the cylinder losing its capacity to hold a load.

![Rod and bearing wear](image)

Fluid motors

In hydraulic motors, the effects of contamination are generally similar to those exhibited by pump wear and result in reduced motor efficiency.

Fluids and fluid terminology

You should understand the following terms:

- **viscosity** – the degree to which a fluid resists flow. As temperature increases, viscosity decreases. Honey, for example, has a high viscosity but flows increasingly easily as temperature increases.
- **viscosity index** – a measure of a fluid’s resistance to, or rate of, viscosity change with change in temperature; the higher the index number, the less viscosity will change with heating. Ideally, in hydraulics, a fluid’s viscosity would remain constant at different temperatures.
- **demulsification** – the prevention or breaking down of liquid–liquid emulsions. A fluid’s demulsification properties will determine the degree to which it resists mixing with water. Demulsifiers allow the rapid separation of water from a hydraulic fluid.

Dirt in a hydraulic fluid:

- acts as a catalyst in breaking down molecular structure, causing gummy residual ‘varnish’
- attacks the oil additives and changes the composition of the fluid.

Proper maintenance of hydraulic systems should keep troubles to a minimum. Experience has shown that proper and efficient running of hydraulic equipment is almost entirely in the hands of the user. For example, an analysis of a manufacturer’s call-outs to customers’ plants showed that 70 per cent of typical service calls were the result of improper condition of the oil concerned; dirty oil; incorrect oil type; water in the oil (rust); lacquer, varnish and sludge formation; or lint and/or other contaminants in the oil. Oil with good demulsification properties will not only resist mixing with water but allow rapid separation of oil and water mixtures.
Oxidation in a hydraulic fluid occurs when oxygen combines with the original hydrocarbon molecules and produces a chain reaction. Traces (even a few parts per million) of certain metals – particularly copper, iron, zinc and lead – and water act as catalysts and markedly increase the rate of oxidation.

Oxidation produces soluble as well as insoluble products and these may form sticky substances which may be deposited as gum or sludge in oil passages, various pump parts, valve spools and ports etc. This may result in blocking and the restriction of oil flow, thereby making the machine run sluggishly.

High operating temperatures severely stress hydraulic oil and, when it overheats, lacquers are formed. As lacquer deposits build up, friction between moving components increases – causing further temperature rise and escalation of the problem.

Varnish deposits in hydraulic oil are a result of oxygen in the oil and frequent draining of a hydraulic system will help to reduce the formation of gum and lacquer.

**Contaminants**

Typical contaminants that may be found in a hydraulic system include:

- dirt and dust
- grease from cleaning rags
- metal chips
- metal particles resulting from normal wear of moving parts
- packing and gasket fragments
- paint flakes
- pipe scale
- pipe-thread compounds
- rust particles
- water
- weld spatter
- incorrect hydraulic oil.

**Maintenance suggestions**

- Set up a filter maintenance schedule and follow it diligently.
- Inspect filter elements that have been removed from the system for signs of failure, which may indicate that the service interval should be shortened or that there are impending system problems.
- Do not return to the system any fluid that has leaked out.
- Make certain that fluid used is of a type recommended by the manufacturer for the system or component. That is, ensure that the fluid is compatible with the system.
- When checking oil level or adding oil to the system, make sure you clean the areas around the dipstick and filler cap before removing them.
Before adding oil, be sure that the existing oil in the system is clean. If it’s not, drain the oil and refill the system completely with new oil that will give good performance under prevailing conditions.

- Use clean containers, hoses and funnels when filling the reservoir. Using a filter cart when adding oil is highly recommended.
- Make sure that all clean-out holes, filler caps and breather cap filters on the reservoir are properly fastened.
- Do not run the system unless all normally provided filtration devices are in place.
- Use common-sense precautions to prevent dirt entering components that have been temporarily removed from the circuit.

**Service tips**

- Clean the machine areas before removing hydraulic components.

  **Note:** When steam cleaning or using water to clean a machine, make sure that filler openings, breather caps etc are protected from possible entry of water into the system.

- Use clean plastic plugs to cover the ends of disconnected lines or to plug openings when you are working on a hydraulic system.
- A clean workbench is an absolute ‘must’ when servicing components. An industrial-type vacuum cleaner is a valuable aid in removing dust, dirt and tiny metal particles from the work area.
- Check the condition of your tools – they should be clean. Always use hammers with heads made of plastic or leather, so there’s no danger of metal chips getting into components.
- When removing parts for service, clean them and then store them in plastic bags or other clean containers until they are installed again.
- Thoroughly rinse the cleaned parts and dry them using clean, dry compressed air. Protect the parts immediately with a coating of rust-preventive oil.
- When cleaning, use extreme care to prevent damage to closely fitted, finely finished parts. Use gum solvents or chemical cleaners to clean metal parts only. Do not allow these cleaners and solvents to come into contact with seals or gaskets.
- Blank off all disconnected lines, hoses and openings.

**Recommended viewing**

*Industrial Hydraulic Technology* video series:

1. ‘Halt Hydraulic Headaches’
2. ‘Understanding Filtration’.
Activity 3 – Principles of hydraulic maintenance

The following questions are designed to allow you to check your understanding of the principles of hydraulic maintenance. Check your answers with your lecturer or supervisor.

Question 1
List the four key maintenance problems common to hydraulic systems.

1. ___________________________________________________________________
2. ___________________________________________________________________
3. ___________________________________________________________________
4. ___________________________________________________________________

Question 2
List three advantages of using a preventative maintenance program for a hydraulic system.

1. ___________________________________________________________________
2. ___________________________________________________________________
3. ___________________________________________________________________

Question 3
Explain why it is important to manipulate the hydraulic valves when flushing a system.

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

Question 4
Explain why you should not use your hands to locate a hydraulic leak.

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

_____________________________________________________________________
Question 5
Circle the correct answer.

Frequent draining of a hydraulic system will help to reduce the:

a) formation of gum and lacquer
b) number of filter inspections
c) need for system suction filters
d) need for return line filters.

Question 6
Circle the correct answer.

Cylinder drift or creep is an example of:

a) external leakage
b) desired cylinder movement
c) cylinder fine control
d) internal leakage.

Question 7
Explain the difference between internal and external leakage.

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

Question 8
List five contaminants that may be found in hydraulic systems.

1. _________________________________________________________________
2. _________________________________________________________________
3. _________________________________________________________________
4. _________________________________________________________________
5. _________________________________________________________________
Question 9
Circle the correct answer.

Varnish deposits in a hydraulic oil are a result of:

a) anti-wear additive breakdown
b) oxygen in the oil
c) glycol in the hydraulic system
d) dirt particles in the hydraulic oil.

Question 10
List two effects that contaminants may have on a hydraulic cylinder.

1. ___________________________________________
2. ___________________________________________

Question 11
Circle the correct answer.

When doing a filter change on a system, you should:

a) never depressurise the system
b) inspect the filter element for contaminants
c) throw the old filter element away immediately – to prevent contamination
d) all of the above.

Question 12
Circle the correct answer.

When adding oil to a hydraulic system, you should make sure that the new oil:

a) is at the right temperature
b) has a lower viscosity index
c) is compatible with the system
d) is strained through a rag.

Question 13
Circle the correct answer.

When you are servicing a hydraulic system, the maintenance logbooks should be consulted to determine:

a) previous problems
b) cycle times and pressures
c) previous adjustments
d) the latest component and configuration changes
e) all of the above.
Question 14
Explain what is meant by the term *viscosity*.

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

Question 15
Explain what is meant by the term *viscosity index*.

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

Question 16
Explain what is meant by the term *demulsification*.

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

Question 17
Circle the correct answer.

The degree to which a fluid resists flow is called its:

a) viscosity index
b) laminar flow
c) viscosity
d) emulsification.

Question 18
Explain what happens to an oil’s viscosity when the temperature rises.

_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
As you have seen, dirt and other contamination are deadly enemies of hydraulic systems. Use of clean, filtered fluid is essential to the maintenance of optimum performance and efficiency in any hydraulic system.
Section 3 – Hydraulic system testing and diagnosis

What you will accomplish in this section
This section of learning will provide you with underpinning knowledge necessary to enable you to:

- apply basic hydraulic principles
- apply hydraulic safety
- identify and verify causes, faults and malfunctions in a system
- remove and test system/components
- correctly investigate and report on system faults.

Introduction

System performance
System performance depends upon several factors which require careful consideration during the application, design, installation and site location stages. All these parameters should be analysed if the hydraulic system is to operate effectively and efficiently. Loss of system efficiency through pressure and/or flow-rate drop is very costly in terms of machine downtime and lost production. Hydraulic problems that affect system flow and pressure are not always easy to locate. This section provides a clear and concise guide to system testing and troubleshooting. The troubleshooting charts towards the end of the section are designed to make the fault-finding process easier and faster. However, if the problem is not readily solved and inadequate flow rate and/or pressure continues, a portable hydraulic tester should be used.

Before any test procedures are carried out, the manufacturer’s specifications must be obtained and studied to determine whether the hydraulic components are operating within design specifications – or are having impossible system demands placed upon them.

Effects of a drop in system flow rate
Reduced flow rate will affect the speed and cycle time of the hydraulic machine; actuators will not extend, retract or rotate at the required speed. Actuator control will become jerky with inconsistencies in flow as cylinders and motors are supplied at different rates. In many complex hydraulic systems, the sequencing and positioning of component operations will be affected as cycle times become thrown out of programmed control. The quickest method of checking a system’s performance is to check the cycle time with a stopwatch.
The pump’s flow rate should be checked first to ensure that the drop in flow is not a result of internal leakage or incorrectly set pump controls. A high temperature at the pump is often a sign of excessive leakage as a result of internal wear within the pump.

Flow rate drops linked to hydraulic motors, control valves and leaking seals may only be detected through using a portable hydraulic tester.

**Effects of drop in pressure**

Pressure drop is essentially a change in hydraulic energy. Resistance to flow caused by friction converts pressure to heat energy. A drop in pressure affects the work capability of a hydraulic machine. The result is a reduction in the amount of work, such as force and torque, that the system produces. Machines lose efficiency, as the cylinders can no longer operate effectively at set pressure and force requirements. The torque capabilities of hydraulic motors are seriously impaired. Some motor designs require high initial pressure to start the motor – so pressure drop will not only affect the motor’s running torque but also start-up torque.

Hydraulic components are dependent upon precise pressure settings and will become erratic in operation or will not fulfil their circuit function if pressure drops below pre-set limits. Systems that depend upon a constant pressure to operate should be designed with a back-up accumulator to overcome safety problems which might arise through sudden pressure drops.

The major causes of pressure drop include:

- pipework restrictions, for example incorrect sizing
- fitting restrictions and sharp corners
- fluid temperature rises
- incompatible hydraulic fluid
- incorrect pressure settings
- sudden enlargement in fluid conductors
- long lengths of fluid conductors
- component leakage (internal and external)
- broken valve springs
- blocked pressure filters
- valves not sealing correctly because of contaminants
- some combination of the above causes.

A combined drop in flow rate and pressure will affect the power requirements of a hydraulic machine, especially in mobile applications, where the speed of the prime mover will have to increase to meet system demand. Pumps powered by electric motors cannot increase their revolutions to provide greater flow rate. Hydraulic motor performance is affected in terms of a drop in power (torque and speed capabilities).

Actuators convert hydraulic energy back into mechanical energy. It is here that lack of flow and pressure instigates the fault-finding process. Jerky cylinder and motor movements are unacceptable and the combination of these hydraulic faults results in a machine’s power performance dropping. The problem must be solved to ensure efficient operation.
System testing procedures

Hydraulic systems, like all machines, require routine maintenance to ensure reliability. However, there are still times when problems occur and must be located quickly and efficiently, especially in production applications. A step-by-step method has been devised as a way of finding solutions to hydraulic problems quickly.

These steps are as follows.

**Step 1 – Know the system**
Study the machine’s technical specifications to obtain an understanding of how the system operates and the function of the machine’s components. Obtain a circuit drawing and check the system through. Check the machine’s maintenance records and commissioning test results, if they are available.

**Step 2 – Ask the operator**
Determine the symptoms of the problem by asking the operator for a detailed description of the machine’s normal operating performance.

**Step 3 – Inspect the machine**
Use your senses (sight, smell, hearing and touch) to locate problems or damage such as high oil temperatures, milky or foaming oil, oil leaks, malfunctioning components and damaged fluid lines.

**Step 4 – Operate the machine**
Operate the machine at its correct operating temperature. Check that the machine’s gauges are reading ‘normal’ and that there are no unusual noises. The operation of the machine’s controls should not be ‘sticky’ or ‘spongy’. The machine’s performance should not be slow, erratic – nor non-existent.

**Step 5 – List the possible causes**
Once the fault has been located and recognised, list the possible causes – starting with the simplest.

**Step 6 – Reach a conclusion**
Use a troubleshooting chart to check the list of possible causes; then decide which is the most probable cause.

(A troubleshooting guide has been included towards the end of this section – for both study and reference purposes.)

**Step 7 – Test the conclusion**
Before starting any repairs to the system, test the conclusion on the cause of the problem. It may be necessary to use a portable hydraulic tester to substantiate the conclusion.
Possible causes

**Symptom 1 – overheating of fluid**

**Action to locate cause:**
- Check oil level.
- Check sufficient water is circulating in heat exchanger.
- Check that cooler’s oil and water space is clear and metal surfaces clean.
- Check to ensure system is not overloaded.
- Check to ensure fluid has not been contaminated with incorrect fluid.
- Check for leakage due to worn pump or valve parts.

**Symptom 2 – slow operation**

**Action to locate cause:**
- Check actual operation pressure.
- Check fluid level for loss.
- Check suction filter.
- Check breather filter on reservoir.
- Check for contamination with incorrect fluid.
- Check relief valves.
- Check for internal leaks.

**Symptom 3 – erratic action**

**Action to locate cause:**
- Check suction filter.
- Check breather filter on reservoir.
- Check for air in system.
- Check for contaminative solids in system.
- Check for contamination of fluid by incorrect fluid.
- Check for wear in pumps and valves.

**Symptom 4 – air in the system**

**Action to locate cause:**
- Check fluid level.
- Check that correct grade of fluid is being used.
- Check method of topping up fluid.
- Check for leaks in suction line.
- Check for leaks in delivery lines.
- Check to ensure return vent is submerged in fluid.
- Check to ensure fluid is not pouring over baffle in reservoir.
- Check whether a vortex is forming at suction inlet.
System temperature
Heat causes hydraulic oil to break down faster and lose its effectiveness sooner. This is why cooling of the oil is needed.

In many systems, enough heat is dissipated through the lines, components and reservoir to keep the oil fairly cool. But on high-pressure, high-speed circuits, oil coolers are needed to dissipate the extra heat.

Overheating
Overheating a system can:

- break down the oil
- damage the seals
- cause coating of parts with varnish deposits
- cause extra leakage past working parts
- reduce the output of the system.

The oil in your hydraulic system was designed for operation within a specified temperature range. You may be able to run it at hotter temperatures for short periods intermittently, without bad effects. But if you operate continuously with oil that’s too hot, your equipment will perform poorly – and eventually key components will fail and halt your machine.

How hot is ‘too hot’?
Hot oil is a relative term. In most cases 50–55 °C at the reservoir is considered an ideal operating temperature. Always take the temperature of oil at the reservoir, not at a component or in any of the piping.

Some hydraulic systems are designed to operate at 55 °C or higher. If you don’t know the maximum operating temperature for your equipment, check the operator’s manual or ask your equipment supplier.

Measuring oil temperature
There are several ways to check the temperature of hydraulic oil. The best and most accurate method is by means of a thermometer. On some machines, one of these is mounted on the reservoir. Make a habit of checking the thermometer periodically, once the equipment has been running for more than an hour.

Isolating trouble spots
To determine which components are running hot and overheating the oil, feel the outlet fittings and lines at the valves, pumps and motors. If oil is at normal temperature when entering a component but hot on leaving, that component could be a trouble spot.

A sticking valve can cause excessive heat. If a spool does not return promptly to the neutral position, the pump flow will be dumped continuously. This builds up heat rapidly.

If a relief valve is set too low, part of the oil will be dumped across the valve on every cycle. This too, generates excessive heat. Even when all valves are set properly, they may not be operating well because of worn orifices or seals.
Look, smell and feel
Checking oil temperature periodically is good preventive maintenance. So, too, is the practice of periodically siphoning an oil sample from the reservoir and comparing it with a sample of clean, new oil.

Oil that’s been running too hot will look darker and feel thinner than new oil. It will also smell ‘burned’. It will probably contain more contaminants, because hot oil leads to accelerated wear of component parts.

Preventative measures
You can help keep your equipment’s hydraulic system from running too hot by adhering to the following preventative measures.

- Set up a regular schedule for checking the level, temperature, appearance, smell and feel of the oil. Change oil as recommended by the equipment manufacturer.
- Be prompt in removing, checking and repairing or replacing valves, pumps or other components that are in need of maintenance.
- If relief or flow-control valves are running hot, check and adjust their settings following the owner’s manual.
- Break in new components gradually. New, close-fitting parts may expand at different rates and are especially prone to seize when they get too hot.
- Keep equipment clean. A thick layer of dirt acts as an insulator. It will prevent heat from dissipating.
- On hot days, and in hot climates, check/change the oil more frequently. Be sure to use oil recommended for hot-weather operation by the equipment manufacturer or oil supplier.

Hydraulic system leaks
There are hundreds of causes of leaks – but they fall into two general categories: internal and external.

Internal leakage does not result in actual loss of oil from the system – but it does reduce system efficiency. External leakage results in direct loss of oil – and can have other undesirable effects as well.

Internal leakage
Internal leakage as a thin oil film is ‘built into’ the working parts of a hydraulic system by design. This lubricates the mating surfaces of valve spools, cylinder pistons and other moving parts. Oil is not lost through this normal internal leakage, because it eventually returns to the system reservoir.

However, too much internal leakage will slow the operation of the system and waste power through generation of heat. In some cases, it may cause cylinders to creep or drift – or cause loss of oil control in the valves.

Internal leakage increases with the normal wear of parts. Leakage is accelerated by using oil which has too low a viscosity, because such oil thins faster at higher temperatures. High pressures also force more oil out of leaking points in the system. This is one reason why excessive pressures can actually reduce the efficiency of a hydraulic system.
Internal leaks are hard to detect. All you can do is monitor the system for sluggish action or creeping and drifting. If these signs appear, it’s time to test the system and pinpoint the trouble.

**External leakage**

External oil leaks not only look bad but also can be expensive and hazardous. A drop of oil every second from a leaking container can cost the operator a significant amount of money.

A small drip of oil can also be a sign of an impending hydraulic failure, such as a hose rupture, which might cause injury and/or put the machine out of operation.

Every joint in a hydraulic circuit is a potential point of leakage. This is why the number of connections in a system should be kept to a minimum.

Components can leak – but care in the assembly and use of new seals and gaskets during overhaul will help to reduce this problem.

The lines that connect the different parts of the system are the main sources of external leakage. Proper fitting and maintenance of hoses, tubes and pipes are important to reduce this problem.

The following are among key points to remember when checking for leakage.

- If the reservoir oil level is lower than normal, check all external oil lines for leaks.
- The rubber cover on flexible hoses may crack or split without actually leaking – but check very closely for internal damage. The depth of the crack is the deciding factor. Any oil dampness is a sign that the hose is leaking.
- Air leaks in suction lines are hard to locate. One way of finding them is to pour oil over the points where you suspect leaks. If the noise or bubbling in the system stops, you've located the leak.
- If line connections are leaking, tighten only until the leak stops. If the connection will not stay tightened, the threads are probably stripped and the connector must be replaced. If the connector will tighten but still leaks, check for a cracked line flare or a damaged seal. Remember, more damage has been done to line connectors by over-tightening than by any other cause.
- After stopping leaks in a system, remember to warm it up and cycle the equipment and check at the trouble spots to be sure leaks have stopped.
- Recheck the system oil level and replace any oil lost through leaks or broken connections.
Checking the system

**Control valves** – Check for sticking valves, leaks and security.

**Pumps** – Check for leaks, noisy operation and slow operation.

**Cylinders** – Check for improper mounting, leaks – and exposed rods during storage.

**Oil lines** – Check for oil and air leaks, loose connections, proper support and pinched and dented lines.

**Reservoir** – Check for low oil level, milky oil and foaming oil and check temperature.

*Figure 7: system checks*

After repairs

After repairs on a system, check the whole circuit for leaks, proper oil level, overheating etc. Do this before operating the system on the job.

For accurate checks, warm up the system and cycle the hydraulic equipment. Start the motor and run the machine for 15 minutes to warm up the hydraulic system. Then run the equipment through its working cycle at least four times, to bleed air from the system.

Add oil if necessary – and operate the machine until the equipment will function smoothly at its full rated capacity.

With the equipment at rest and the motor shut off, recheck the oil level. If necessary, add oil to bring it to the proper level.

**Important:** Always check the oil level after any repairs to a system. Also check the system periodically during operation. Follow the machine operator’s manual to determine proper intervals.
Regular checks
Some checks that should be done regularly are outlined below.

Checking reservoir and oil
- Check the reservoir oil level and the condition of the oil frequently.
- At this time, also check for other malfunctions in the system. Look for:
  a) air bubbles or foaming oil — which might indicate an air leak somewhere in the system.
  b) change in oil level. If there's a noticeable change in the oil level from day to day, look for leaks or cracks in the external parts of the system.
  c) milky oil — which would indicate water in the system or in the oil used. Make sure that oil is stored properly.
- Before removing the filler cap, wipe away all dirt and grime on and around it. If a dipstick is used for checking oil, wipe it with a clean, lint-free cloth.
- Before adding oil, make sure that the existing oil in the system is clean. If not, drain the oil and refill the system completely with new oil that will give good performance under prevailing conditions. However, if the drained oil contains sludge, sediment or gum and lacquer formations, the system should be cleaned and flushed before refilling.

Checking cooler, lines and connectors
- Clean the oil cooler periodically and check it for leaks. Keep the fins clean on air-to-oil coolers. Check for corrosion in water–oil types.
- Check oil lines, hoses and connectors at regular intervals. Look for:
  a) pressure oil leaks. Oil leaks in the pressure side of the system can be located by examining the outside of lines and fittings.
  b) air leaks. If the suction side of the system is drawing in air, the oil in the reservoir will bubble and foam.
  c) pinched or dented lines — which can cause oil foaming, overheating and loss of hydraulic power.

Replace damaged hoses or tubes at once. Wash lines inside and out with clean solvent before installing them.
- Tighten any loose lines or connections. Use two set spanners to avoid twisting hose or tubes. Replace any connectors that continue to leak.

Important: Tighten loose connectors only until the leak stops. Don’t use excessive force to stop fluid leakage; otherwise the component body may be distorted or cracked.

Checking valves
Dirt will cause valves to stick or work erratically. Also, after long use, valve spools may become worn, allowing oil to leak past them. Check all valves for leaks periodically — and service them.
Checking cylinders
Check cylinders periodically for both external and internal leakage. Make sure cylinders are mounted properly. Make sure that the rods of exposed cylinders are not left extended when the machine is stored; otherwise, the rods will collect dirt and moisture, which might cause rusting or pitting of the rods. If the rods must be exposed, make sure they are coated with a heavy grease.

Checking motors
Never permit a hydraulic motor to overheat. If it is running hot, make sure the oil supply is adequate and also check the system oil cooler to make sure it is functioning properly. Also inspect for leaks at the motor hose connections, around the shaft, at the seals and at mating surfaces.

What is good maintenance?
Good maintenance involves good work habits, such as making sure you always do the following.

- Use common sense.
- Stop, look, touch and listen before picking up tools.
- Change oil and filters regularly.
- Maintain good records.

GOOD
- cleanliness
- high-quality oil
- proper filters
- tight seals
- normal operation

BAD
- dirt
- water
- air
- heat
- abuse

System testing methods

Recommended viewing
Industrial Hydraulic Technology video series:
‘Flow meter hook-up’.

Tee testing
‘Tee testing’ checks system efficiency and enables faulty components to be isolated for repair or replacement. More than one ‘tee test’ may need to be performed to pinpoint a faulty component.
The three major system checks for which ‘tee testing’ is used are:

- ensuring the pump is producing its recommended flow rate (test performed with connection to the control valve plugged)
- checking that the relief valve is operating at the correct pressure setting
- checking component leakage.

Pump test

Flow rate problems in hydraulic systems often originate at the pump as a result of internal wear or incorrect settings on pump controls. If the cause of a flow rate problem cannot be easily pinpointed, a portable hydraulic tester is used to measure the system’s flow at various points in the circuit; the pump’s flow rate is usually measured first.

![Figure 8: pump test](image)

The manufacturer’s specifications or pump-commissioning data provide a reference against which any future flow readings are compared. This comparison enables a pump’s efficiency to be determined. (Refer to the discussion on leakage testing under Hydraulic system leaks earlier in this section.)

To evaluate a pump’s output, the tester is installed in the circuit between the pump outlet and the inlet to the directional control valve or before the relief valve, as illustrated in Figure 8. The system is run until normal operating temperature is reached.

The tester’s loading valve is fully opened to allow full flow at zero pressure. The valve is then progressively closed through a series of predetermined pressure ‘steps’ and the flow and pressure readings are recorded. The level of decrease in flow between the minimum and maximum pressure settings will indicate the pump’s condition. A typically worn or damaged pump will lose 20–30 per cent flow capability. Low flow at both minimum and maximum pressure indicates inlet problems.
Relief valve test

To test a relief valve, the tester is installed in the circuit after the relief valve, with the outlet of the tester connected to the reservoir. When the loading valve on the tester is fully opened, the pump’s flow passes through the tester and back to the reservoir, bypassing the control circuit. The loading valve is then slowly closed while pressure and flow readings are observed. The pressure will increase until the relief valve opens and diverts the flow back to the reservoir via the relief valve. When the relief valve’s operating pressure setting is reached, there should be a zero reading on the tester’s flow meter.

![Tee testing for leakage in control valves and cylinders](image)

The pressure setting should be recorded and adjusted if it is incorrect. It is not unusual for a relief valve to start opening below the maximum pressure setting, causing considerable leakage and loss of machine performance. Direct-acting relief valves are prone to this problem; pilot-operated relief valves are not – and are preferred. The cracking pressure can be checked by slowly increasing the pressure until the flow through the tester starts to fall away.

Tee testing for leakage in control valves and cylinders

The tester is inserted into the system between the pump and control valve, with its return line connected back to the reservoir. Start the system and warm the hydraulic oil to normal operating temperature. Extend the cylinder to the end of its stroke. On multiple-spool valves, only one spool should be in the ‘power’ position at any one time.

The leakage test for a directional control valve (DCV) is conducted by closing the tester’s loading valve and monitoring the flow and pressure readings. Leakage is determined by subtracting flow readings on the tester from the system flow readings determined during the pump test. If the flow readings of the valve equal the pump test flow readings, the valve is in good condition. If all valve leakage readings are similar, the tests indicate the component is functioning correctly even if test readings are somewhat below the flow readings of the pump test. The manufacturer’s recommendations and the application will determine whether any leakage can be tolerated.
The relief valve should be checked first if all the flow readings (leakage) from mullet-banked control valves are the same. If the ‘tee test’ does not pinpoint the leakage to either the control valve or cylinder, an additional test may be required.

By disconnecting the line to the cylinder and plugging the valve port, the control valve can be tested separately. Place the handle of the control valve in the position at which the greatest decrease in flow was noted in the previous test; then close the tester’s loading valve and record the pressure and flow readings. If the decrease in flow is the same as that in the first test, the control valve is at fault. But, if the flow readings are higher and comparable to those of the other control valve spools, the excessive leakage is due to a faulty cylinder.

**Figure 10: ‘tee testing’ control valves and cylinders**

**Motor in-line testing**

The tester may be used in an in-line test to evaluate the condition of valves, motors, cylinders and pumps.

The performance of a hydraulic motor is checked by measuring the flow rate and comparing it to equivalent motor speed. The tester is installed in the line before the motor – which is determined by the motor’s direction of rotation. The hydraulic system is run to reach operating temperature with the tester’s loading valve fully open. The motor is run under normal load and flow and pressure readings are noted. If the flow rate is below the manufacturer’s specifications or lower than that recorded in the pump test, check the control valve. The motor’s speed (revolutions per minute) should be
recorded when it is working at normal pressure. If the motor’s speed is low and the inlet flow found to be correct, the motor’s internal leakage is excessive and will not be acceptable.

**Note:** If the motor does not have an external drain or cannot be back-pressure-loaded, the tester must also be connected on the other side of the motor to repeat the test in the opposite direction.

An alternative method of motor testing is to disconnect the motor from the system and connect the tester in its place. By pressurising the flow through the tester, the flow rate can be compared to manufacturer’s specifications and the pump test flow rate figures. If the motor test flow figures are lower, the directional control valve should be checked. But, if the flow is correct and the speed of the motor slow, the motor is defective.

![Figure 11: motor test](image-url)
Activity 4 – Principles of hydraulic system testing
The following questions are designed to allow you to check your understanding of the principles of hydraulic system testing. Check your answers with your supervisor or lecturer.

Question 1
List three parameters that can be tested by a portable hydraulic tester.

1. ___________________________________________________________________
2. ___________________________________________________________________
3. ___________________________________________________________________

Question 2
Explain why the load valve on a hydraulic tester must be open before starting up a system.

_____________________________________________________________________
_____________________________________________________________________

Question 3
In logical sequence, list the seven steps that should be followed when diagnosing hydraulic system problems.

1. ___________________________________________________________________
2. ___________________________________________________________________
3. ___________________________________________________________________
4. ___________________________________________________________________
5. ___________________________________________________________________
6. ___________________________________________________________________
7. ___________________________________________________________________
Question 4
List five major causes of pressure drops in hydraulic systems.

1. ____________________________________________
2. ____________________________________________
3. ____________________________________________
4. ____________________________________________
5. ____________________________________________

Question 5
List four possible causes of fluid overheating in hydraulic systems.

1. ____________________________________________
2. ____________________________________________
3. ____________________________________________
4. ____________________________________________

Question 6
List four possible effects of fluid overheating on a hydraulic system.

1. ____________________________________________
2. ____________________________________________
3. ____________________________________________
4. ____________________________________________

Question 7
What is considered to be the normal operating temperature of a hydraulic system as measured at the reservoir?

___________ °C
Hydraulic circuitry and components

The main parts that make up a hydraulic system are:

- the reservoir
- filters
- coolers
- the pump
- valves
- actuators
- pressure gauge.

Reservoirs

The main storage area for fluid in a hydraulic circuit is known as a reservoir. This is sometimes integrated into the hydraulic machine but, in other cases, is a separate container which is conveniently located in an external power pack. A typical reservoir is constructed as shown in the figure below but some reservoirs contain additional equipment to improve system performance. The reservoir not only stores oil but also helps to keep the system clean and free of air. It also reduces the oil’s operating temperature.

Figure 12: main components of a standard reservoir
Reservoir parts

**Filler cap** – This should be airtight when closed but usually contains an air vent with a filter to allow in atmospheric pressure for proper oil flow.

The filter must be kept clean in order to prevent blockage of air flow and the creation of a partial vacuum, which would restrict oil flow to the system.

**Oil-level gauge** – This indicates the oil level in the reservoir but a dipstick may be used in difficult locations.

**Baffles** – These prevent the hot return oil from mixing with cooler oil entering the pump. This separation also allows contaminants in the return oil to settle and any air to separate from the oil.

**Outlet and return lines** – These are designed to keep turbulence in the oil to a minimum. Their ends should be approximately 50 millimetres from the bottom of the tank and pointed at the wall.

**Intake filter** – This is usually a screen positioned in the pump inlet to prevent large particles from entering the system.

**Drain plug** – This allows all oil to be drained from the reservoir. Some drain plugs are magnetic so that they remove iron and steel particles from the oil.

**Manhole** – This access panel allows cleaning and inspection of the reservoir.

**Servicing a reservoir**

Manufacturers usually recommend certain time periods between hydraulic oil changes. If the system is working under extremely hot conditions or if the correct oil level is not maintained in the reservoir, the oil will overheat and start to chemically break down, necessitating servicing. This can be observed – because the oil will change colour. It may also lose its ability to lubricate the moving parts within the hydraulic equipment, which could cause an expensive breakdown. If the oil in the reservoir drops below the low-level mark on the gauge, it must be replenished to the correct level. Mobile equipment must be on reasonably level ground when an oil level check is carried out.

If the reservoir oil is dirty or has a bad odour, it’s time to have the oil checked by a qualified person. If necessary, the system should be flushed and the oil replaced.

**Filters**

Because hydraulic fluid not only transmits power but also acts as a lubricant for the moving parts in a hydraulic system, it is most important to prevent its contamination with dust, metal particles or other contaminants.

Contaminated oil can jam a precisely fitted valve spool. Its abrasive action can ruin the close tolerance required for satisfactory sealing of a valve. Even a grain of sand in a tiny orifice can put a whole machine out of operation. Very small particles of foreign material cause wear as they pass through the small orifices of hydraulic equipment and may lodge between moving valves and housings, causing permanent scratches on hard surfaces.

The air surrounding hydraulic equipment is often the major source of contamination. Another source is the normal wearing of components – which produces metal particles – during operation of the system.
Filter applications
Three kinds of filter are used to perform different jobs in a hydraulic system.

Air vent filters
These prevent contamination of the hydraulic fluid by polluted air surrounding the system.

Inlet strainers
These filters are positioned in the reservoir and connected to the inlet line of the hydraulic pump. They remove some of the larger impurities from the oil before it reaches the pump.
Oil filters

Oil filters are used to prevent contamination of the fluid in a hydraulic system by collecting wear debris and contamination such as dirt particles. Some filters have a bypass valve that will allow the passage of oil should the filter become blocked. Others may have pressure indicators to monitor the condition of the filter.

Filter construction, rating and maintenance

All three kinds of filter (described above) consist mainly of fine, porous material which allows only clean air or oil to pass through and so prevents the fluid being contaminated by solid contaminants. Filters belong to one of two basic groups according to design. They are:

- the depth type, which filters the fluid through a series of layers of material such as long strands of synthetic or metal fibres – or even paper
- the surface type, which traps contaminants on the surface of a woven mesh.

Hydraulic filters are rated as absolute, nominal or beta – according to the size of particle removed and their efficiency.

Regular maintenance is ‘a must’ for filtration units. Poor servicing will render them useless for filtering out contaminants. A highly contaminated or blocked filter will cause an increase in pressure resulting in the hydraulic fluid bypassing the filter via an internal check valve. If a strainer becomes blocked with impurities, only a small quantity of oil will reach the pump. A high-pitched scream will be emitted from the inlet side of the oil-starved pump. The imbalance between the demand and supply of oil causes cavitation, which is one of the major causes of permanent pump failure – with resulting expensive repair work.
Cavitation results when the pressure at the pump inlet is less than the vapour pressure of the fluid being pumped. If a liquid’s temperature rises enough or pressure is substantially reduced, vapour bubbles will form within it. This phenomenon is called cavitation and, in the broad sense, includes the formation of bubbles when water is boiled. In the case of a hydraulic pump, as the pressure increases at the pump’s outlet, vapour bubbles caused by cavitation will implode or collapse, producing a shock wave which will damage the pump’s internal components. This is usually identified by pitting and the removal of metal from pump components.

If the reservoir oil level is low, air will be induced into the pump and aeration of the oil will take place, causing it to froth and reducing lubrication of the pump. This will also cause rapid wear of pump assemblies and the hydraulic system will have a ‘spongy’ feel to the controls.

**Recommended reading**

Pages 117–22, on ‘Filters, pressure switches and gauges’, in *Industrial Hydraulic Control* (Rohner).
Activity 5 – Principles of oil filtration

The following questions are designed to allow you to check your understanding of the principles of oil filtration. Check your answers with your supervisor or lecturer.

Question 1
Name the three ratings used to classify hydraulic filters.
1. ___________________________________________________________________
2. ___________________________________________________________________
3. ___________________________________________________________________

Question 2
Explain the difference between a depth and surface type of filter.
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

Question 3
List three kinds of filters with different applications in a hydraulic system.
1. ___________________________________________________________________
2. ___________________________________________________________________
3. ___________________________________________________________________

Recommended reading
Pages 107–110, on ‘Reservoirs’, in Industrial Hydraulic Control (Rohner), including Activity 15.
Activity 6 – Reservoirs
The following questions are designed to allow you to check your understanding of the function of the reservoir in a hydraulic system. Check your answers with your supervisor or lecturer.

Question 1
List three functions that are performed by a reservoir.
1. _______________________________________
2. _______________________________________
3. _______________________________________

Question 2
Explain the function of the baffle in a reservoir.
________________________________________
________________________________________
________________________________________

Question 3
Explain the effect that an intake filter with a small micron rating will have on a hydraulic system.
________________________________________
________________________________________
________________________________________

Question 4
Explain why some hydraulic reservoirs are pressurised.
________________________________________
________________________________________
Oil coolers

In modern hydraulic systems, cooling the oil can be a significant problem. The normal circulation of the oil around the system, through the reservoir, will no longer do the job in many cases. For this reason, oil coolers are becoming common on modern equipment. The two types of coolers widely used are air-to-oil coolers and water-to-oil coolers.

An air-to-oil cooler uses moving air to dissipate heat from the oil. The cooler has fins that direct air over oil tubes, which cool the oil.

A water-to-oil cooler uses moving water to remove heat from the oil. The water flows through a series of tubes and the oil circulates around these tubes. On mobile machinery, water from the engine radiator is often used for cooling.

Pumps

The pump is the heart of a hydraulic system. It converts mechanical or electrical power, supplied from the prime mover, into hydraulic power. The mechanical operation of the pump moves the fluid from the reservoir into the system. The major function of the pump is to produce fluid flow; any resistance to this flow will produce pressure in the system.

All modern hydraulic systems use positive displacement pumps. Such pumps have a mechanical seal between the inlet and outlet ports, causing a predetermined volume of oil to be pumped every cycle. The seal prevents system pressure causing leakage across the pumping chamber and back to the reservoir.

Non-positive displacement pumps do not have a seal across the pumping chamber, so some fluid can leak back across from the outlet port to the inlet port. An example is the centrifugal pump commonly used for pumping water at low pressure.

Principle of the hydraulic pump

Hydraulic pumps are designed on the following principle. A partial vacuum is created at the inlet port, allowing atmospheric pressure to force fluid into the inlet side of the pump from the reservoir. The pump’s mechanical action forces the fluid to and through the outlet port.

The essential requirements in any hydraulic pump are:

- a low-pressure inlet port supplied with fluid from the reservoir
- a high-pressure outlet or delivery port connected to the system
- a pumping chamber, which allows the fluid to be moved from the inlet to the delivery port
- internal pumping components (for example, piston, vanes or gears) to positively move the fluid from the inlet to the delivery port
- an internal seal to prevent oil leakage across the pumping chamber
- an external seal on the pump to prevent fluid leakage to atmosphere
- connection of the pumping chamber to a drive unit.
Maintenance notes

All pumps must be operated at the speeds and pressures recommended by the manufacturer; any deviation from these specifications may reduce a pump’s working life or result in pump failure.

Cleanliness is essential when working on pumps. Any small pieces of foreign material which find their way into small clearances of pump assemblies will cause excessive wear – which will be expensive to rectify.

The amount of internal leakage from a pump’s outlet to inlet is known as slippage and must be kept to a minimum. Excess slippage causes heat generation.

Valves

The fluid flow generated by the pump through a hydraulic system has to be directed and controlled at all times. If the fluid pressure and flow is not controlled, the system might not be used effectively by the operator or the machine may even self-destruct.

One of the advantages of a hydraulic system is that the energy can be controlled with relative ease by using a selection of the following control valves: directional control valves, pressure-control (relief) valves and flow-control valves.

Directional control valves

A directional control valve controls the direction of fluid flow. It consists of a valve body and a moving part which selectively directs or prevents fluid flow to a specified channel.

Do not neglect a small leak in a hydraulic circuit, because pressure will soon enlarge a small score mark in a seal.

Relief valves

A relief valve provides a hydraulic system with protection from overload. This is achieved by setting a maximum pressure for the system and diverting all or part of the pump output to the reservoir when the maximum pressure is reached.

Relief valves will activate to provide overload protection if:

- an actuator stalls due to excessive load
- a cylinder bottoms out at the end of its stroke
- a cylinder is in a force-holding position during a pressure cycle (nil flow required)
- the system's flow demand is less than the pump's delivery – for example, if the pump outlet flow is 30 litres per minute and the system demand is five litres per minute.

All hydraulic systems using positive displacement pumps are fitted with a relief valve for system protection; otherwise system pressure would build up until permanent damage was done to the pump or a hydraulic line, which might burst and cause injury.

The simplest form of relief valve comprises just a valve body and spring-loaded poppet. Such a valve is known as a direct-operated relief valve. The valve is normally in closed position, held shut by the preloaded spring. When system pressure exceeds the spring tension at the base of the poppet, the poppet lifts, allowing fluid to pass the poppet and
flow to the reservoir. When pressure drops, the spring forces the poppet downwards and the pressure port is closed. When pressure builds up again, the valve opens again. In this way, continuous operation is maintained.

**Maintenance notes**

Any excessive noise from a relief valve should be investigated, because, under normal conditions, relief valves should be reasonably quiet in operation.

Once a relief valve has been set, it is often a good idea to remove the handle of the adjustment screw to prevent inexperienced operators from ‘over-adjusting’ the valve and thus creating a safety hazard.

If difficulty is experienced in shifting loads with a machine, the relief valve should be checked because too much oil might be returning to the reservoir, leaving insufficient pressure for the main hydraulic system to do the work.

When servicing a pilot-operated valve, cleanliness is essential at all times. This is because the operating clearance of the piston is very small, so even small pieces of foreign matter in the oil will cause damage.

**Flow-control valves**

A flow-control valve consists of a valve body with inlet and outlet ports. An adjustment orifice within the valve body can be used to restrict the valve’s output flow. The function of a flow-control valve is to reduce the flow of oil from the pump to the actuator.

With fixed-displacement pumps, increased fluid back-pressure increases pump operating pressure, which, once maximum allowable system pressure is reached, in turn opens the circuit relief valve, to return the excess fluid flow to the reservoir. It must be remembered that, if pump flow is severely restricted, excessive relief valve operation will cause overheating of oil, resulting in costly repairs.

**Actuators**

The function of an actuator is to convert hydraulic energy to mechanical energy.

An actuator may be linear or rotary. A linear actuator (cylinder or ram) produces force and motion in a straight line, while a rotary actuator (motor) produces torque and rotational motion.

**Linear actuators**

These are more commonly called hydraulic cylinders or rams. They are used for clamping and lifting and for traverse and feed motions.

*Cylinder cushions* are often installed at one or both ends of a cylinder to slow movement down near the end of the stroke and prevent the piston from hammering against the end cap.

A *cylinder stop tube* is a spacer placed on the cylinder rod next to the piston in a cylinder with long strokes. The stop tube provides increased side-loading support to the rod, thus minimising the chance of rod or bearing failure.

**Maintenance notes**

When cylinders are dismantled for inspection, the work area must be perfectly clean. A sheet of paper over a bench will assist in keeping parts clean.
Carefully dismantle the actuator, taking care that parts are not damaged. Inspect all parts for abnormal wear. Any parts showing abnormal wear should be put aside for a qualified opinion.

Inspect the inside of the cylinder, looking for score marks and at the condition of the surface finish. The cylinder may be free of score marks but may be distorted, which would cause the ram to flex as it extended from the cylinder.

If a small leakage of oil is noted on the ram shaft, the cylinder end plate seals may be suspect.

Carefully inspect piston seals for wear, because it is these that prevent oil leakage around the piston.

When assembling an actuator, it is important that all seals be given a coating of oil before installation. Also, care must be taken that the shafts or cylinders slide smoothly through the seals; otherwise small slivers of seal material may be peeled off, causing premature failure of the assembly.

Situations may arise in which circuit pressure is correct but the cylinder will not deliver a force. This is the result of oil leakage from the high-pressure side of the actuator to the low-pressure side. Some operators may mistakenly blame the pressure relief valve or pump – but the cause is piston seal leakage.

Under no circumstances should attachments be welded or fitted to cylinders, because this causes distortion and resultant rapid deterioration of the actuator assembly.

**Rotary actuators**

The motor is designed much like the pump. Both use the same basic type of construction – that being gear, vane or piston. Often parts from one can be substituted in the other.

The major difference is that a hydraulic motor works 'in reverse' to a pump. The pump drives the fluid, while the motor is driven by the fluid. A pump draws in fluid and pushes it out, converting mechanical force into fluid force. In the case of a hydraulic motor, fluid is forced in, converting fluid force into mechanical force. The work output of the motor is called **torque**. It is the rotary force applied by the motor to the drive shaft.

The ratio between the speed and torque output of a motor depends upon the volume of fluid it displaces with each cycle.

**Maintenance notes**

Hydraulic motors are manufactured to very fine engineering tolerance and therefore are very expensive.

Regular inspection of motors should be carried out in order to determine whether oil leakage is taking place.

If dampness is noticed at the output shaft seal, this should be reported before high-pressure flow of oil takes place.

Internal leakage or slippage may be checked on models fixed with external drains by measuring the amount of leakage oil returned to the reservoir in a given time – with the system at operating temperature.

Connections of hydraulic tubes or flexible hoses should be inspected. If leakage is noticed at a threaded connection, the fitting should be checked for tightness, care
being taken not to over-tighten or strip threads. Sealing tapes or chemicals may also be used to eliminate leaks from threaded connections.

Do not subject a motor to ‘shock loading’ by rapid operation of the direction valve, because this would set up a high-pressure pulsation in the motor, causing damage to some of the components.

Fluid connectors

Pipes and tubes
A pipe is recognised by its inside diameter and a tube by its outside diameter.

It is usual to have piping between the reservoir and pump inlet – and tubing after the pump, where high pressure is developed.

Piping connections are threaded and are now described according to size in metric terms. Any leakage at these connections is unacceptable, so Teflon® tape should be wound around the thread, in the same direction as the thread, before a connector is finally tightened.

It is important to remember that Teflon® tape lubricates the thread as it seals, so care must be taken not to over-tighten. Teflon® tape should not be used on flares – only on threads.

Tubing is usually sealed at connections by a standard flare and nut – or a bite-type fitting.

Vibration may cause fracture of hydraulic tubing at the point where it enters a component. So regular inspection of hydraulic tubing may avoid trouble by revealing a minor leakage before a major breakdown occurs.

Note: If excessive force is used to tighten tapered fittings into hydraulic components, they will distort or crack the body.

Flexible hoses
Hoses are the best form of hydraulic plumbing for most uses. Not only do hoses allow for motion but they also absorb vibrations and noise, withstand pressure surges and are easy to route and connect.

A hydraulic hose is made up of three basic parts: an inner tube, reinforcement layers in the middle and an outer cover.

The inner tube is a synthetic rubber layer which is oil-resistant. It must be smooth, flexible and able to resist heat and corrosion and must be compatible with the fluids being pumped through the system.

The reinforcement layers vary with hose type. They provide resistance to burst pressure. These layers (or plies) are made of natural or synthetic fibres, braided wire or a combination of these. The strength of the overall layer depends upon the pressure requirements for which the hose is designed. As the number of braids or plies increases, the hose’s pressure rating increases and its flexibility decreases.

The outer cover protects the reinforcement layers. It is usually made of a special rubber which resists the effects of weather, dirt, oil and abrasion.
Pressure gauge
The pressure gauge informs the operator of circuit pressure.
If the pressure tends to fall below that set by the pressure relief valve, the operator will know there’s a malfunction in the circuit.
As the operation of a pressure gauge is partly mechanical, circuit pulsations may rapidly cause damage.
Sometimes an isolator valve is positioned in the circuit before the gauge – and opened only when circuit pressure is to be checked.

Accumulators
An accumulator stores hydraulic pressure and may be used in a circuit as either or both of the following:
- a safety device, in case of temporary failure of the main power source or system leakage during a holding cycle
- a shock absorber, to absorb high-pressure pulsations that would normally cause pressure-related breakdowns in the circuit.
The bladder type of accumulator contains nitrogen compressed to circuit pressure. If a high-pressure pulsation occurs in the system’s oil, the nitrogen compresses and absorbs the pulsation which might otherwise cause leakage.
In the case of a temporary circuit failure, the nitrogen expands and oil in the accumulator is forced into the failing circuit to keep it operating.
A poppet valve at the base of the accumulator prevents the bag from extruding through the outlet.

Maintenance notes
Never dismantle any connection from an accumulator even if the engine is stopped, because oil will still be under pressure and injury may result.
If nitrogen leaks from an accumulator, it must be recharged by a qualified person. Do not attempt to put air into a leaking accumulator, because the result may be an explosion when pressure is developed.
A drop of soapy water, placed on the nitrogen valve, will indicate whether there is any gas leakage to the exterior.
If you suspect an internal leak, check for foaming oil in the system reservoir and/or inaction of the accumulator. These signs usually indicate a faulty bladder or faulty piston seals inside the accumulator.
If an accumulator appears to be in good condition but nevertheless is slow or inactive, pre-charge it as necessary.
Troubleshooting in hydraulic systems

Troubleshooting is the ‘tracking down’ and elimination of the cause of a problem in a system. It requires the ability to analyse a hydraulic system and a logical approach to identifying the problem area. It is bad practice to begin removing components from a hydraulic circuit without having a logical plan. *Whenever there is doubt, call in someone who is qualified*. It will save time and probably money.

To undertake troubleshooting on a hydraulic system, you need to:

- understand how the circuit works
- understand how the components in the circuit affect each other
- read ‘telltale’ signs presented by the circuit
- test components within the circuit and relate the results to the problem.

**Recommended viewing**

*Industrial Hydraulic Technology* video series:
1. ‘Troubleshooting Techniques’
2. ‘Applied Troubleshooting’
3. ‘Analysing Component Faults’.

Knowing the system

Probably the greatest help in troubleshooting is confidence in knowing the system. Every component has a purpose in the system. The construction and operating characteristics of each one should be understood.

You should:

- know the **capabilities of the system**. Each component in the system has a maximum rated speed, torque or pressure. Loading the system beyond the specifications simply increases the possibility of failure.
- know the **correct operating pressure**. Always set and check pressures with a gauge. How else can you know if the operating pressure is above the maximum rating of the components?

Sometimes there may be a question over the correct operating pressure. If it isn’t correctly specified on the hydraulic circuit drawings, apply the following rule. Take the correct operating pressure as the lowest pressure which will allow adequate system function while remaining below the maximum pressure rating of the components and machine. Once correct pressures have been established, note them on the hydraulic schematic for future reference.

- know the **proper signal and feedback levels and dither and gain settings** in servo-control systems. If they aren’t specified, check them when the system is functioning correctly and mark them on the schematic for future reference.
Recognising indications of trouble
The ability to recognise indications of trouble in a specific system is usually acquired with experience. However, a few general indicators can be discussed.

Excessive heat
Excessive heat means trouble. A misaligned coupling places an excessive load on bearings and can be readily identified by the heat generated. A warmer-than-normal return line from a relief valve to a tank indicates the valve is operating at its relief setting. Hydraulic fluids which have a low viscosity will increase the internal leakage of components, resulting in a heat rise. Cavitation and slippage in a pump will also generate heat.

Excessive noise
Excessive noise could indicate wear, cavitation or that there’s air in the fluid. Contaminated fluid can cause a relief valve to stick and chatter. Unusual noises may be the result of dirty filters or fluid, high fluid viscosity, excessive drive speed, low reservoir level, loose intake lines or worn couplings.

Developing schematic procedures
Analyse the system and develop a logical sequence of setting valves, mechanical stops, interlocks and mechanical controls. Tracing of flow paths can often be accomplished by listening for flow in the lines or feeling them for warmth. Develop a cause-and-effect troubleshooting guide similar to the fault charts shown later in this section. The initial time spent on such a project can save hours of system downtime.

Circuit reading
The following seven circuit diagrams and related questions should help to develop your skills in fault finding.
Activity 7 – Circuit reading

The following questions are designed to allow you to check your understanding of the principles of circuit reading and fault finding. Check your answers with your supervisor or lecturer.

Referring to Circuit 1:

1. Which way do the cylinders move when the DCV (A) is deactivated?

_________________________________________________________________

2. List two possible causes of the cylinders extending at different rates.

a) ___________________________________________________________________

b) ___________________________________________________________________

3. What is a possible cause of the cylinders retracting too quickly?

_________________________________________________________________
Referring to Circuit 2:

1. What is the purpose of the push-button DCVs (A and B)?

2. What is the purpose of the adjustable check valve (C)?

3. Why is there a check valve (D) on the pump's discharge filter?
Referring to Circuit 3:

1. Which way does the motor rotate when the left-hand solenoid of the DCV (E) is activated?

___________________________________________________________________

2. Assuming that the pump and its relief valve are serviceable, list two possible causes of the motor having low torque in the anticlockwise direction.

a) _________________________________________________________________

b) _________________________________________________________________

3. What is the function of the two check valves (A and B) located directly under the motor?

___________________________________________________________________

4. What is the function of the two relief valves (C and D) located directly under the motor?

___________________________________________________________________

5. What would be a possible cause if, after it was activated, the DCV (E) would not return to its centre position?

___________________________________________________________________

6. What is the centre condition of the DCV (E)?

___________________________________________________________________

7. What position would the DCV (E) take if there was an electrical power failure?

___________________________________________________________________
Referring to Circuit 4:
1. Circle the correct response. What type of hydraulic system is illustrated in this circuit?
   - Open loop
   - Closed loop

2. How is the motor’s speed controlled in this unit?

3. What is the function of the two check valves (A and B) under the motor?

4. What would happen to the motor if the spring of the right-hand relief valve (C), located under the motor, failed?

5. Would the above occurrence affect the circuit operation in the other direction?

6. What would happen if the cross-line relief valves were set at different pressures (for example, one at 25 MPa and the other at 35 MPa)?

7. What would happen to the circuit if the boost pump relief valve was set at a higher setting than the cross-line relief valves?
Circuit 4
Referring to Circuit 5:

1. What is the purpose of the DCV (A) in this circuit?

_________________________________________________________________

2. In what direction would the motor be rotating if the DCV (A) had moved to the left?

_________________________________________________________________
Referring to Circuit 6:
1. What is the function of the two check valves (A) in this circuit?

2. With a coloured pencil, trace the pressure and return oil paths from the cylinders (B). Assume the DCV (C) has been moved to the left.
Referring to Circuit 7:

1. Why does the circuit have two pumps?

2. What is the purpose of the left-hand pump (A)?

3. What is the purpose of the 2/2 DCV (B) located at the right-hand cylinder?

4. What is the maximum pump pressure of the circuit?

5. List a possible cause of the right-hand cylinder (C) extending prematurely.

6. Identify the function of the valve (D) which is set at 18 MPa.

7. Identify the function of the valve (E) which is set at 5 MPa.

8. Explain what would happen if the 12 MPa valve (F) was adjusted to a new value of 16 MPa.

9. Identify the valve labelled G.
Circuit 7
Fault-finding charts

The following five charts are designed to make fault finding easier and quicker. They are provided for both study and reference purposes.

Each chart addresses a major symptom which would indicate some type of malfunction in a hydraulic system. For example, Chart 1 is entitled *Excessive system noise* and deals with three specific symptoms – noisy relief valve, noisy pump and noisy motor – under this general symptom heading. In the case of a noisy pump, you would refer to the chart’s Row B – which sets out four possible causes, ordered according to the likelihood of occurrence or ease of checking. The first cause listed is *air in the oil* – for which the solution would be Remedy 2, as set out at the bottom of the chart. If the first cause did not apply, you would check for the second cause listed. All five charts are designed in a similar way and are to be used in the manner described in the above example.

<table>
<thead>
<tr>
<th>Chart 1</th>
<th>Excessive system noise</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specific symptom</strong></td>
<td><strong>Possible cause</strong></td>
</tr>
<tr>
<td>A Noisy relief valve</td>
<td>setting too low or too close to another valve setting</td>
</tr>
<tr>
<td></td>
<td>Remedy 4</td>
</tr>
<tr>
<td></td>
<td>worn poppet and seat</td>
</tr>
<tr>
<td></td>
<td>Remedy 5</td>
</tr>
<tr>
<td>B Noisy pump</td>
<td>air in the oil</td>
</tr>
<tr>
<td></td>
<td>Remedy 2</td>
</tr>
<tr>
<td></td>
<td>coupling misaligned</td>
</tr>
<tr>
<td></td>
<td>Remedy 3</td>
</tr>
<tr>
<td></td>
<td>cavitation</td>
</tr>
<tr>
<td></td>
<td>Remedy 1</td>
</tr>
<tr>
<td></td>
<td>damaged or worn pump</td>
</tr>
<tr>
<td></td>
<td>Remedy 5</td>
</tr>
<tr>
<td>C Noisy motor</td>
<td>coupling misaligned</td>
</tr>
<tr>
<td></td>
<td>Remedy 3</td>
</tr>
<tr>
<td></td>
<td>coupling or motor damaged or worn</td>
</tr>
<tr>
<td></td>
<td>Remedy 5</td>
</tr>
</tbody>
</table>

**Remedies:**

1. Any or all of the following: replace dirty filters; wash strainers in solvent compatible with system fluid; clean clogged inlet line; clean reservoir breather vent; change system fluid; select correct pump driver speed; replace or overhaul boost pump; hydraulic oil is too cold.
2. Any or all of the following: tighten leaking inlet connections; fill reservoir to proper level; bleed air from system; replace pump shaft seal.
3. Perform alignment check. Inspect condition of seals, bearings and coupling.
4. Using a pressure gauge, set to correct pressure.
5. Overhaul or replace.
## Chart 2

<table>
<thead>
<tr>
<th>Specific symptom</th>
<th>Excessive system heat</th>
</tr>
</thead>
</table>
| **A** Hot pump              | heated oil
Remedy 4  
cavitation  
Remedy 1  
air in the oil  
Remedy 2  
relief or unloading valve set too high  
Remedy 4  
excessive load  
Remedy 3  
damaged or worn pump  
Remedy 5 |
| **B** Hot motor             | heated oil
Remedy 4  
relief or unloading valve set too high  
Remedy 4  
excessive load  
Remedy 3  
damaged or worn motor  
Remedy 5 |
| **C** Heated relief valve   | heated oil
Remedy 4  
valve setting too high  
Remedy 4  
damaged or worn valve  
Remedy 5 |
| **D** Hot oil               | system pressure set too high  
Remedy 4  
fluid level low or dirty  
Remedy 6  
icorrect fluid viscosity  
Remedy 6  
relief or unloading valve set too high  
Remedy 4  
faulty oil cooler  
Remedy 7  
damaged or worn pump, motor, valve, cylinder or other component  
Remedy 5 |
Remedies:

1. Any or all of the following: replace dirty filters; wash strainers in solvent compatible with system fluid; clean clogged inlet line; clean reservoir breather vent; change system fluid; select correct pump driver speed; replace or overhaul boost pump.

2. Any or all of the following: tighten leaking inlet connections; fill reservoir to proper level; bleed air from system; replace pump shaft seal.

3. Perform alignment check. Check condition of seals, bearings and coupling. Check for mechanical binding. Check whether workload is in excess of circuit design.

4. Using a pressure gauge, set to correct pressure. (Keep at least 1 MPa difference between valve settings.)

5. Overhaul or replace.

6. Change filters and system oil if not of correct viscosity. Fill the reservoir to the correct level.

7. Clean the cooler and/or cooler strainer. Replace cooler control valve. Repair or replace the cooler.
<table>
<thead>
<tr>
<th>Specific symptom</th>
<th>Possible cause</th>
</tr>
</thead>
</table>
| **A  No flow**   | pump not receiving any oil  
Remedy 1  
pump drive motor not operating  
Remedy 5  
sheared pump drive coupling  
Remedy 3  
pump rotating in wrong direction  
Remedy 7  
prime mover direction control in wrong position  
Remedy 6  
all oil passing over relief valve  
Remedy 5  
damaged pump  
Remedy 3  
correctly assembled pump  
Remedy 5 |
| **B  Excessive flow** | flow control set too high  
Remedy 4  
swash plate/yoke malfunction  
Remedy 5  
prime mover revolutions per minute incorrect  
Remedy 8  
incorrect size of pump  
Remedy 8 |
| **C  Low flow** | flow control set too low  
Remedy 4  
relief or unloading valve set too low  
Remedy 4  
flow passing through a partially open valve  
Remedy 5 or 6  
external leak in system  
Remedy 2  
worn pump, valve, motor or cylinder, or other component  
Remedy 5  
swash plate/yoke malfunction  
Remedy 5  
prime mover revolutions per minute incorrect  
Remedy 8 |
Remedies:

1. Any or all of the following: replace dirty filters; wash strainers in solvent compatible with system fluid; clean clogged inlet line; clean reservoir breather vent; check system oil level; replace or overhaul boost pump.

2. Tighten leaking connections. Bleed air from system.

3. Check for damaged pump or pump drive. Perform alignment check.

4. Adjust to proper setting.

5. Overhaul or replace.

6. Check the position of manually operated valves. Check electrical circuit on solenoid-operated controls. Repair or replace boost pump.

7. Reverse rotation.

8. Replace with correct unit.
## Chart 4

<table>
<thead>
<tr>
<th>Specific symptom</th>
<th>Incorrect pressures</th>
</tr>
</thead>
</table>
| **A** Low pressure | a pressure-relief path exists  
Remedy: See Chart 3, Rows C & A  
pressure-reducing valve set too low  
Remedy 4  
pressure-reducing valve damaged  
Remedy 5  
damaged pump, motor or cylinder  
Remedy 5 |
| **B** No pressure | no flow  
Remedy: See Chart 3, Row A |
| **C** Excessive pressure | pressure-relief, -reducing or -unloading valve maladjusted  
Remedy 4  
swash plate/yoke malfunction  
Remedy 5  
pressure-relief, -reducing or -unloading valve worn or damaged  
Remedy 5 |
| **D** Erratic pressure | air in oil  
Remedy 2  
worn pressure-relief valve  
Remedy 5  
fluid contamination  
Remedy 1  
accumulator defective or has lost its charge  
Remedy 3  
worn pump, motor or cylinder  
Remedy 5 |

**Remedies:**

1. Any or all of the following: replace dirty filters; wash strainers in solvent compatible with system fluid; replace system fluid.
2. Tighten leaking connections. Bleed air from system.
3. Check gas-charging valve for leakage. Charge to correct pressure. Overhaul if damaged.
4. Adjust to proper setting.
5. Overhaul or replace.
Chart 5

<table>
<thead>
<tr>
<th>Specific symptom</th>
<th>Faulty system operation</th>
</tr>
</thead>
</table>
| **A** No movement | no pressure or flow  
See Chart 3  
sequence or limit device (electrical or  
mechanical) not functioning  
Remedy 5  
mechanical binding  
Remedy 2  
no command signal to servo amplifier  
Remedy 6  
servo amplifier out of adjustment or  
inoperative  
Remedy 3  
servo valve malfunction  
Remedy 5  
damaged or worn cylinder or motor  
Remedy 5 |
| **B** Slow movement | low flow  
Remedy: See Chart 3  
high fluid viscosity  
Remedy 1  
low valve-control pressure  
Remedy: See Chart 4  
lack of lubrication of machine slides  
or linkages  
Remedy 7  
servo amplifier out of adjustment  
or inoperative  
Remedy 3  
sticking servo valve  
Remedy 4  
damaged or worn cylinder or motor  
Remedy 5 |

(Continued overleaf)
### Chart 5 – continued

<table>
<thead>
<tr>
<th>Specific symptom</th>
<th>Faulty system operation</th>
</tr>
</thead>
</table>
| **C** Erratic movement | Erratic pressure  
Remedy: See Chart 4 |
|                  | air in the oil  
Remedy: See Chart 1 |
|                  | lack of lubrication of machine slides or linkages  
Remedy 7 |
|                  | erratic command signal  
Remedy 6 |
|                  | servo amplifier out of adjustment or inoperative  
Remedy 3 |
|                  | feedback transducer malfunction  
Remedy 5 |
|                  | sticking servo valve  
Remedy 4 |
|                  | damaged or worn cylinder or motor  
Remedy 5 |
| **D** Inconsistent movement | Excessive flow  
Remedy: See Chart 3 |
|                  | malfunction of feedback transducer  
Remedy 5 |
|                  | servo amplifier out of adjustment or inoperative  
Remedy 3 |
|                  | overriding by workload  
Remedy 8 |

### Remedies:
1. The fluid may be too cold or it should be changed with fluid of the correct viscosity.
2. Locate the bind and repair accordingly.
3. Adjust, replace or repair.
4. Clean, replace or adjust. Check the condition of the system filters.
5. Replace or overhaul.
6. Repair the command console or the interconnecting wires.
7. Lubricate.
8. Repair or replace and adjust the counterbalance valve to proper setting.
Activity 8 – Fault finding and diagnosis

The following questions are designed to allow you to check your understanding of the principles of fault finding and diagnosis in hydraulic systems. On completion of this activity, check your answers with your supervisor or lecturer.

Answer each question by selecting and circling one of the choices provided.

Question 1
The recommended working temperature (measured at the reservoir) of a hydraulic system using mineral oil is normally around:

a) 25–40 °C
b) 50–55 °C
c) 65–75 °C
d) 75–90 °C.

Question 2
Many portable analogue hydraulic testers are electronically operated and battery-powered. If the battery were faulty, which of the following tests might still be performed with most testers?

a) oil temperature check
b) pressure test
c) checking pump speed (revolutions per minute)
d) system leakage test.

Question 3
Which of the following problems in a hydraulic system would result in hot oil, pump damage and loss of actuator control?

a) aeration
b) cavitation
c) incorrect pump speed
d) incorrectly set relief valve.

Question 4
If the machine’s cylinder is allowing the workload to overrun, which of the following control valves requires attention?

a) flow-control valve
b) system-relief valve
c) unloading valve
d) counterbalance valve.
**Question 5**
Which of the following problems would cause a large drop in system pressure when the machine was under load?
- a) relief valve opening as a result of excessive pressure
- b) pump slippage
- c) oil viscosity being too high
- d) oil flow bypassing through a partially open control valve
- e) problems a) and d).

**Question 6**
A hydraulic cylinder is operating with a jerky motion and the fluid temperature is high. Which of the following machine problems is the likely cause?
- a) high oil level
- b) pump slippage
- c) cavitation
- d) incorrectly set counterbalance valve.

**Question 7**
Which of the following hydraulic machine tests is the quickest method of checking a system’s performance?
- a) a ‘tee test’
- b) a pump test
- c) a leakage test
- d) a cycle-time test with a stop-watch.

**Question 8**
If the temperature gauge on the side of the oil reservoir indicates an increase in system temperature and the machine’s cycle time has increased, the problem would be:
- a) an incorrectly set relief valve (pressure too high)
- b) incorrect oil selection (too high a viscosity)
- c) contaminated oil
- d) pump slippage.

**Question 9**
A motor is stalling under a light load. Which of the following system faults could be diagnosed as the reason for this?
- a) faulty directional control valve
- b) faulty flow control
- c) pump cavitation
- d) incorrectly set relief valve.
Question 10
When testing a hydraulic motor’s performance, the portable tester should be connected into the system:

a) using the ‘tee test’ method
b) in parallel with the motor
c) directly between the pump and the return line filter
d) in series with the motor.

Question 11
Internal cylinder leakage is identified by:

a) cylinder drift
b) incorrect relief valve setting (pressure setting too low)
c) incorrect end-cushioning setting
d) cylinder bounce.

Question 12
A loose connection on the inlet side of a pump will cause:

a) an increase in the system’s operating temperature
b) aeration
c) cavitation
d) loss of system pressure
e) problems a) and b).

Question 13
Incorrect selection of hydraulic fluid could cause which of the following system problems?

a) slow system operation
b) pump cavitation
c) pump slippage
d) high system temperature
e) all of the above.
We value your comments!

If you:

– have any suggestions about how this guide might be improved
– think that any information should be added, removed or updated
– consider there should be more or different practical activities

then please write your comments in the space below and send this page to the following address.

Metals, Mining & Engineering
Swan TAFE
PO Box 1336
Midland WA 6936

Changes I would like to see: ______________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________
_____________________________________________________________________

Ref: MEM18021B Learner’s Guide
MAINTAIN HYDRAULIC SYSTEMS
MEM18021B

Learner’s Guide

This learner’s guide is part of a series of resources developed for students undertaking units from Certificate IV in Engineering (Fluid Power). It covers content and activities derived from the unit MEM18021B Maintain hydraulic systems.

CATEGORY
Engineering, Mechanical and Electrical

TRAINING PACKAGE
• MEM05 – Metal and Engineering

COURSE/QUALIFICATION
• MEM40105 Certificate IV in Engineering (Fluid Power)

UNITS OF COMPETENCY
• MEM18021B Maintain hydraulic systems

RELATED PRODUCTS
• ENG704 – Certificate IV in Engineering (Fluid Power) Assessment Tools (CD)
• ENG705 – Certificate IV in Engineering (Fluid Power) Practical Workbook 1
• ENG706 – Certificate IV in Engineering (Fluid Power) Practical Workbook 2
• ENG707 – Certificate IV in Engineering (Fluid Power) Student Workbook 1
• ENG708 – Certificate IV in Engineering (Fluid Power) Student Workbook 2
• ENG709 – Certificate IV in Engineering (Fluid Power) Student Workbook 3
• ENG710 – Certificate IV in Engineering (Fluid Power) Student Workbook 4
• ENG970 – Maintain Hydraulic System Components Learner’s Guide
• ENG972 – Maintain Pneumatic System Components Learner’s Guide
• ENG973 – Maintain Pneumatic Systems Learner’s Guide