NSW Resources Regulator

Hydraulic safety

Mining design guideline | MDG 3007

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Foreword

Safety procedures for the maintenance and operation of heavy equipment begin with the understanding that anyone who works with hydraulic machinery must be aware of the potential hazards involved. It is important to follow manufacturer/supplier’s recommended information on assembly, operation and maintenance. The following is general safety information that is often common to these life cycle activities.

The simplicity of control of many hydraulic systems can cause operators to forget the hazards and potential dangers that result from the enormous power and mechanical forces associated with the equipment.

One fraction of a second of carelessness or a simple oversight, could result in serious injury and possibly death.

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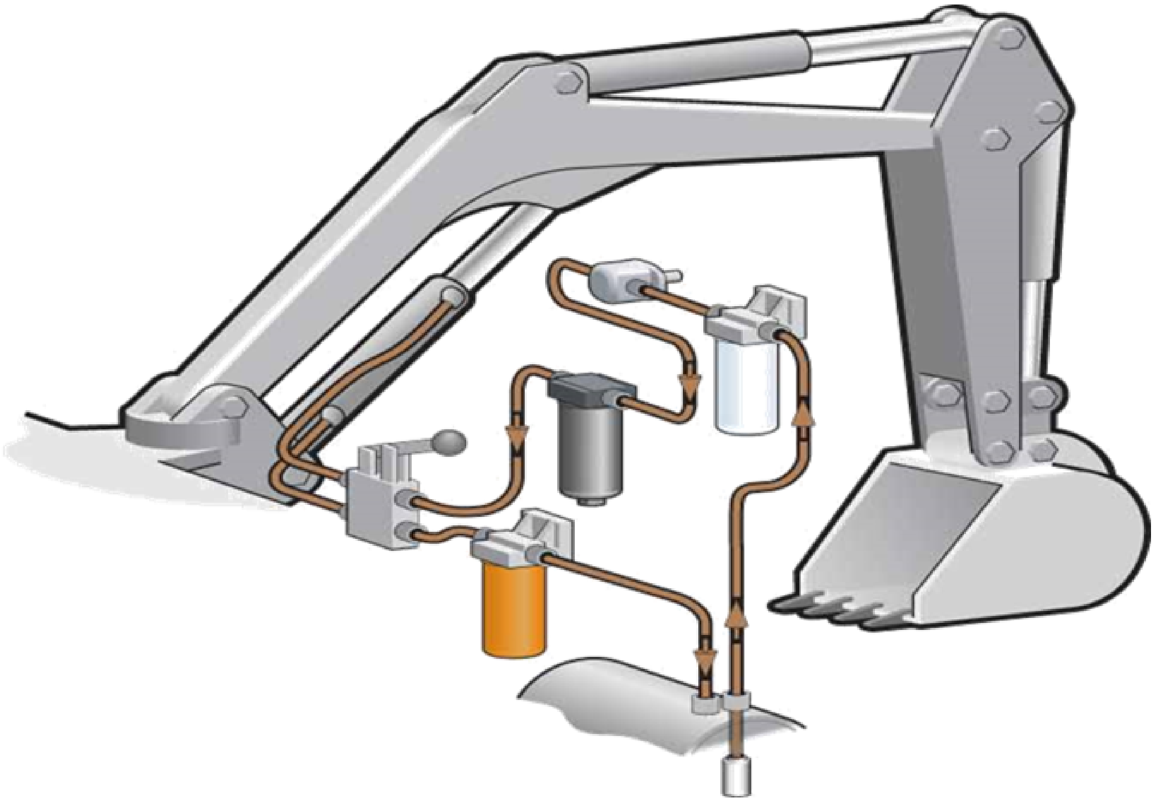
Hydraulic systems

A confined fluid is one of the most versatile means of controlling motion and transmitting power.

Figure 1: Hydraulic hose diagram for boom lift cylinder - arrows show direction of flow



Fluid power or specifically – **hydraulic systems** operate on the following basic principles:

- A hydraulic pump is used to create a flow of an incompressible fluid.
- A pressure can then be generated on a surface by restricting the flow of a fluid.
- If actuators (such as hydraulic cylinders) are placed in the flow of fluid, a pressure will be exerted on the piston of the cylinder, resulting in a mechanical movement of the piston.
- As a result, this mechanical movement causes the arm of the digger to extend or retract. A flow of fluid in the opposite direction will cause mechanical movement in the opposite direction.

Note: Flow makes it go.

Pressure acting on the surface of the piston produces force.

Force from the hydraulic cylinder produces work done by causing the arm of the digger to move.

Hydraulic systems are used in many applications such as trucks, cranes, dumpers, bulldozers and excavators etc.

Figure 2: Hydraulic valve bank with multiple hoses and diffusion sleeves

Before working on any hydraulic circuit always assess the task you are going to do for potential hazards and dangers

This is especially important if attempting a task for the first time or you are unfamiliar with the circuit or system/machine.

Ensure you have a thorough knowledge of the subject. Conduct a thorough assessment of any requirements that may assist in minimising all risks involved with hydraulics. Always use but understand the limitations of **personal protective equipment.**

Ensure you have a diagram of the circuit and you can read, and understand the circuit. Identify all isolation points in the system and any stored energy such as accumulators or load locks on actuators that need to be dissipated.

Effects of gravity on hydraulic componentry causing pressure in the hydraulic system need to be dissipated or components mechanically locked.

Ensure the circuit is hosed correctly and all the protection equipment is in place and correctly set.

Protection may include covers, guarding and hose sheathing/sleeves.

NEVER use part of the hydraulic circuit for any task for which it was not intended.

NEVER feel for leaks.

NEVER vent hydraulic fluid to atmosphere unless it is safely controlled, such as into collection drums/trays or through a diffuser.

NEVER disconnect any line that has not been de-energised and tested for de-energisation

ALL hoses must be connected.

Note: **Isolation** is a process which includes:

- → **Identification** of all energy sources
- → **Provision** for means to isolate the circuit or part of the circuit using **isolation devices** which are preferably lockable.
- → Means to prevent movement of components due to gravity, where required
- → Means to **dissipate residual pressure**
- → Means to **verify** pressure is dissipated and circuit is safe to operate on
- → **Safe work procedures**
- → **Competent people**

For detailed advice on ISOLATION see Section 3.6 in MDG 41 “Fluid Power System Safety at mines”. www.resourcesandenergy.nsw.gov.au/__data/assets/pdf_file/0008/419489/MDG-41.pdf

Fluid power systems are often powered by energy sources such as electricity or diesel engines. These power sources must be part of the isolation consideration. Isolate and secure all energy sources.

ALWAYS

A. Isolate (the circuit fully before working on it)

- → The correct valve
- → The power supply

B. Lock

- → The isolation valve in the closed position
- → With personal locks at the isolation point

C. Depressurise the energy source
D. Lock the bleed valve in the open position
E. Verify effective isolation (test for dead)

- → Prove that the line is depressurised
- → Check the gauge is at zero
- → Check fluid no longer passes through the bleed valve

Personal protective equipment

Ensure you have all the correct personal protective equipment (PPE), required to do the task safely.

This may include the following:

- Gloves if required
- Safety Helmet
- Safety Boots
- Safety Attire
- Safety Glasses
- Hearing Protection

Remember: Personnel protective equipment may not protect against fluid injection – for example high pressure will penetrate most gloves.

Operating fluid

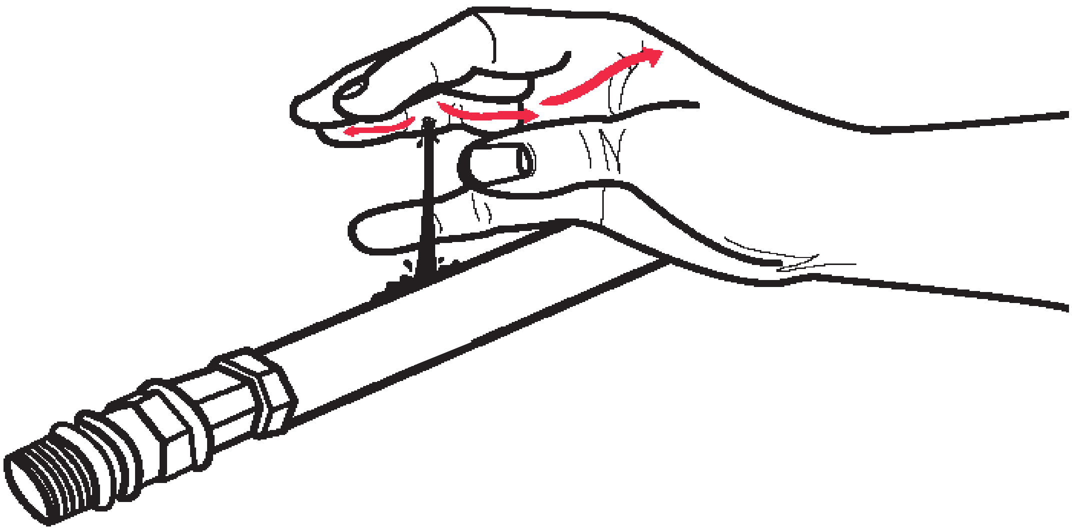
Personal safety

Hydraulic fluids such as oils, phosphate esters and other fluids may be injurious to health and reference should be made to the manufacturer's safety data sheet.

- → Reduce skin contamination to a minimum
- → Use suitable equipment and work methods
- → Do not allow oil to soak into floors or benches - clean up spills immediately
- → Barrier cream may be used for sensitive skins
- → Do not wear oil soaked clothing or shoes for prolonged periods
- → Avoid breathing oil mist or vapours
- → Oils in a hydraulic system are often under high pressure (and may also be hot) so beware of leaking hoses, pipes, etc. -These should be reported/ repaired as soon as possible.

A pin-hole in a hydraulic line operating at 13.7 MPa (2000 psi) will create an oil exit velocity of approximately 1500 kilometres per hour (946 miles per hour) - which could easily penetrate the skin and enter the blood stream. Note that substantially lower pressures can result in serious injury for example to the eyes and other sensitive areas of the body.

Figure 3: fluid injection injury from pin hole in hydraulic hose.



Oil temperature is normally in the vicinity of 60^{0}C depending on the system design.

Some mobile applications often operate at temperatures much hotter than this, sometimes approaching the boiling point of water. Oil burns are painful, serious, and long lasting.

Figure 4: Person in hospital following fluid injection injury.

Hydraulic fluids trapped in the tissue cannot be easily removed and instances of gangrene have often occurred. It is important **not** to put your finger or any part of your body over a jet of fluid that may be observed coming from a faulty hose, fitting or other leak.

Figure 5: Fluid injection injury to hand following surgery.

Fluid escaping from a small hole can be almost invisible.

Searching for fluid leaks by "FEEL" is a dangerous practice and will eventually result in injury to fingers or even your hand. Use a piece of cardboard, wood, paper or a mirror, instead of your hands, to search for suspected leaks.

Figure 6: Looking for hydraulic leaks with a mirror.

Hoses and fittings

All hydraulic components including hoses should always be compatible with the fluid being carried through them. Some fire-resistant fluids (such as phosphate ester) require specialty hoses and seals.

All hydraulic components including hoses should always be manufactured in accordance with recognised standards. Guidance is available in MDG 41 Guideline for fluid power system safety at mines. Hydraulic hoses should have a minimum factor of safety of 4:1 based on hose burst pressure to maximum working pressure (at maximum operating temperature).

Figure 7: Galvanised water pipe elbow - not suitable for hydraulic systems.

Always use appropriate hydraulic fittings.

NEVER use galvanised fittings in hydraulic circuits.

Always check that the hose type and ends are rated adequately for the operating pressures in the system. (Some hose ends like BSP/JIC are not rated at 4:1 safety ratio for their larger sizes.)

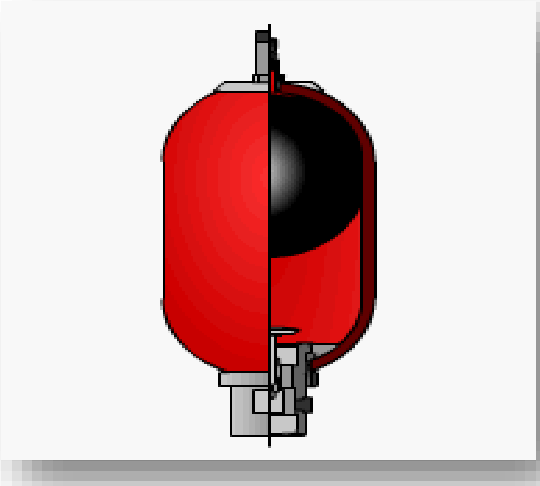
Take care when using Staple type fittings in circuits. They are convenient and allow rapid connection and assembly, but it is harder to determine if the system still retains pressure. Verification of fluid pressure should occur for example through reading a pressure gauge.

Figure 8: Broken BSPP thread on hydraulic hose end.

Never ever re-use a staple. Use a new staple and when installing a staple use a secondary retention method. Components released under pressure may be propelled at high velocity.

Accumulators

Figure 9 and 10: Left - pressure accumulator diagram, Right - photo of failed pressure accumulator.



An accumulator looks a little like a **BOMB** (and can go off like one if not treated properly).

Many hydraulic systems are fitted with an accumulator which is a specially designed pressure vessel and is one of the most potentially dangerous components in the system.

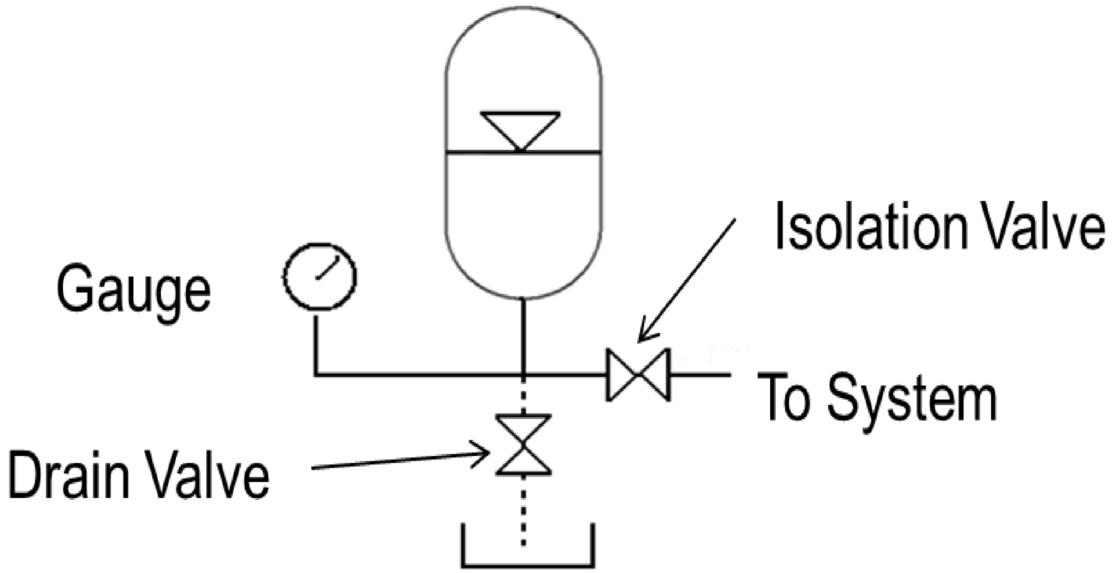
The accumulator can be used to take the place of the hydraulic pump for short periods to maintain system pressure in the event of a power failure or it can be used to absorb shock or pressure surges due to sudden stopping or reversing of oil flow.

AN ACCUMULATOR CAN OPERATE A HYDRAULIC SYSTEM NORMALLY EVEN WHEN THE SYSTEM IS SHUT DOWN AND ISOLATED.

The accumulator **must** be isolated from the circuit or completely discharged **before** attempting to disconnect any hydraulic component.

A specific procedure is required.

If at all unsure, do not proceed with the work.



NEVER try to disassemble an accumulator without **FIRST** releasing the pre-charge gas.

If the accumulator is removed from the circuit **without depressurising**, fluid can be discharged at an uncontrolled rate, and this may cause the accumulator to behave like a **projectile** launching its heavy steel case into the nearest person or object with disastrous results.

An important function of the accumulator is that it generally requires a pressurised inert gas (nitrogen) to function properly.

Nitrogen gas when discharged in a reasonably **confined space** can cause an oxygen deficient atmosphere.

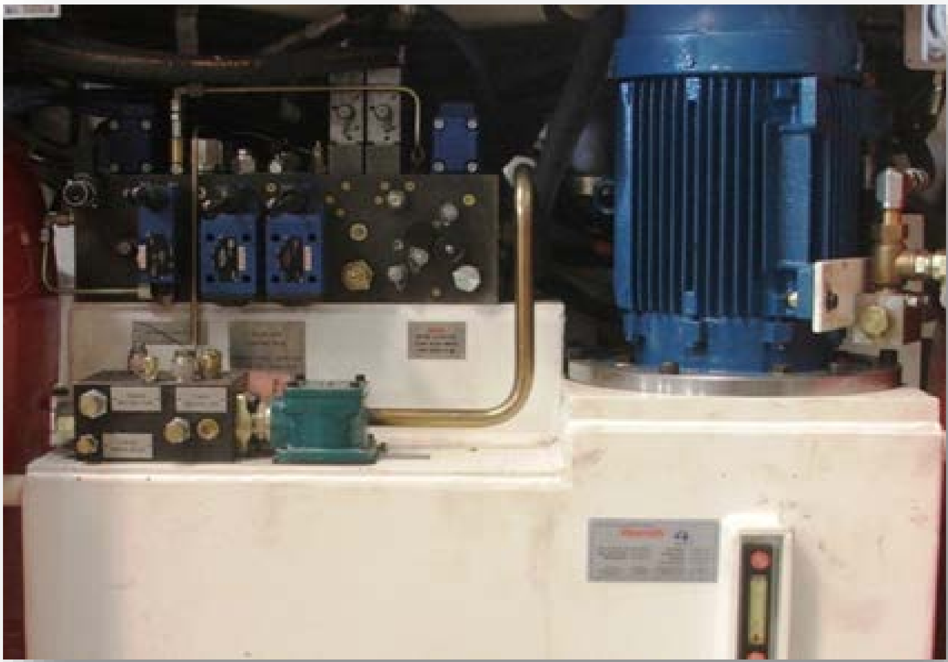
Atmospheres containing less than 18% oxygen are extremely dangerous and at less than 10% will certainly cause brain damage and often death.

Also, while Nitrogen is non-toxic, in high concentrations it is an effective asphyxiant (may result in death).

Hydraulic apparatus

Use extreme care when removing the breather, filler connection, or hose to a reservoir. Many units are pressurised to prevent the entry of contaminants and may discharge hot fluid unless pressure is relieved properly.

Figure 11: Hydraulic power pack.



Faulty control valves

Figure 12: Hydraulic control valve bank.

Load lock valves

Even though load-lock valves are fitted for example to boom lift cylinders on continuous miners and shuttle cars ALWAYS use the mechanical stops provided when working under raised booms or other componentry that is subject to gravitational forces.

Figure 13: Mechanical stop for hydraulic cylinder.

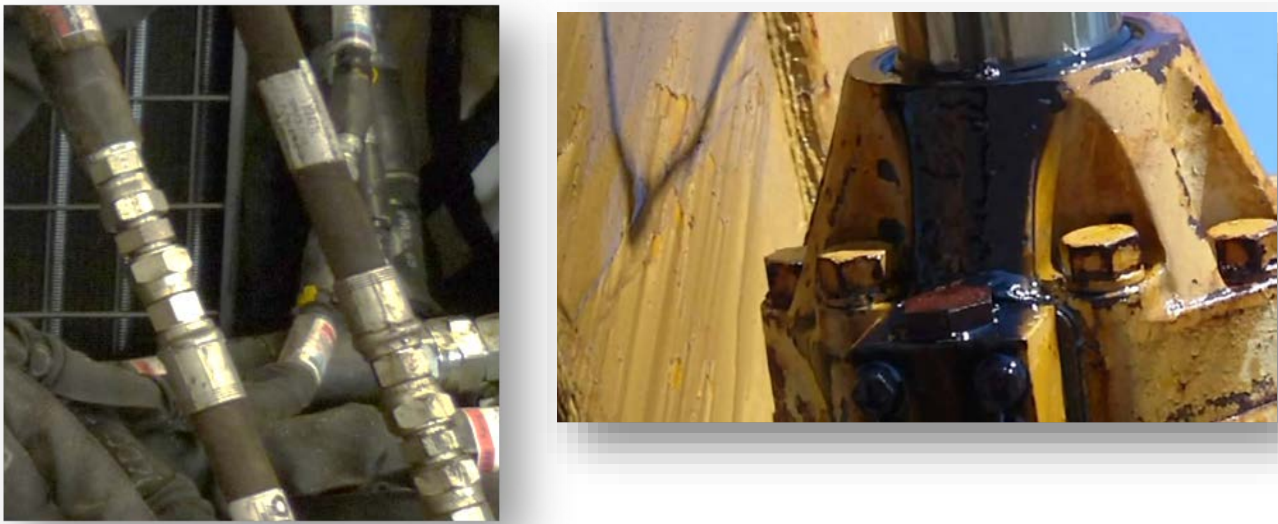
Note: Load-locks and other hydraulic componentry for example cylinders can fail. Hence the need for a mechanical stops as shown in the picture above.

Hydraulic cylinders and actuators

On assembly and prior to testing, ensure all connections and hoses are properly fitted.

Blockages in return flow lines can cause over-pressurisation and intensification well beyond designed system pressure. This may result in dangerous fluid discharge.

Figure 14: Left - multiple hydraulic hoses, Right - leaking rod seal on hydraulic cylinder.



Inspections of hydraulic systems

Be particularly conscious of the following when inspecting a hydraulic system.

Hydraulic lines

- Kinked or chafed hoses
- Hoses in contact with electrical cables
- Dented pipe lines
- Hoses too close to heat sources
- Hoses tangling with moving parts
- Leaks, Weeps and Spills Which Could Indicate
- Loose or cracked fittings or pipes
- Blown O-rings or seals
- Excessive pressure in circuit causing components or hose lines to become stressed
- Wrong fittings or hoses being used

Figure 15: Failed crimping of hose end fitting.

Figure 16: Old failed hoses.

Condition of oil for smell, colour and solid content

- Dark colour together with almond smell usually indicates overheating
- Milky appearance could indicate water inclusion

Unusual vibrations or noises

- This could be due to a mechanical fault
- Fault within the hydraulic system
- Cavitation conditions

Figure 18: Damage from cavitation.

Jerky or unresponsive operations

- Normally due to air entrapped within the hydraulic system
- Faulty accumulator

Excessive shock in the system

- Could indicate incorrect relief valve setting
- Mechanical faults
- Operational faults

Hydraulic tools

Hydraulic power is one of the safest methods of applying force to your work when fit for purpose equipment is used correctly.

Hydraulic tools come in many varieties; and pressures up to 700 Bar (10,000 psi) are common.

Safety tips

When operating hydraulic power tools always wear appropriate personal protective equipment.

- Do **NOT** exceed rated pressure or force capacity of the equipment.
- Hydraulic pressures should **NOT** be applied through kinked hoses.
- DO provide a solid, firm foundation before attempting to lift a load.
- DO NOT rely on pump valving for load holding, securely pack.
- Also NEVER stand over jack handle as it may move violently and unexpectedly!!!
- Never walk under a load supported **ONLY** by hydraulic cylinders.

Off-centre loads should NOT be lifted as they put unnecessary strain on the cylinder rod.

The rated cylinder stroke should **NOT** be exceeded as it puts unnecessary strain on the cylinder plunger, other cylinder componentry and may prevent operation.

General safety rules

Machine shut down procedure

Typical example: a hydraulic loader. After operating a machine there **is** a certain safety shutdown procedure that **should** be observed:

1. Park the machine on level ground and apply the park brake.

DO **NOT** UNDER ANY CIRCUMSTANCES LEAVE A MACHINE WITH THE IMPLEMENTS RAISED AND/OR UNSUPPORTED.

THEN

2. Lower all implements so that there is no hydraulic actuator force required for support.

THEN

3. Turn off the engine and isolate the machine as required.

THEN

4. Operate all the directional control valves through all possible positions to relieve any trapped pressure in the system.

THEN

5. If maintenance or repair work is required on the machine, all actuators and implements must be securely blocked to prevent movement. If an accumulator is fitted, use the correct isolation procedure and verification of depressurisation.

Machine start-up procedure

Before start-up a thorough inspection **should** be performed.

Check for:

- → leaks, weeps and spills
- → frayed hose lines and connectors
- → correct fluid levels.
- → correct operation of all hydraulic controls
- → no stuck controls or valves

THEN

Start the machine and let it run until the system has warmed up.

On initial start-up of a hydraulic system, the actuators may move without notice due to air entrapped in the circuit and actuators. In most cases the system will self- purge after a couple of minutes.

THEN

Operate all actuators a few times to ensure **all the air** is purged from the system and that the actuators are full of fluid.

Recheck the fluid level with the pump running.

Identify and report any hydraulic defects immediately and isolate and tag out any defective equipment.

Remember to be safe

- Don't take short cuts.
- Apply proper safety procedures at all times.
- These good safety habits are essential for **your safety** and the **safety of your co-workers**.