Kelair Pumps Australia Pty Ltd A Mace Group Company ABN 28 001 308 381 215 Walters Road Arndell Park NSW 2148
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PUMP CLINIC 10

PUMP OPERATION AND MAINTENANCE

Index

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TABLE 1 - Centrifugal Pumps - Fault-finding

Fault	Cause	Remedy or Action
Pump not turning	Driver not running	Check fuses, circuit breakers
	Keys sheared	Replace
	Drive belt slip	Check and adjust
	Coupling fault	Check if slipping or broken, replace if necessary
	Shaft or gears sheared	Check, replace if necessary
Pump not priming	Inlet valve closed	Open valve
	Inlet clogged or restricted	Check and clear
	Air leaks on suction side	Replace seals, check line(s) for leaks
	Liquid drained or syphoned from system	Fit check or foot valve to prevent draining
	Worn pump impeller	Inspect, increasing pump speed might help, also fitting foot valve
No discharge	Lack of prime (see also above)	Open all vent cocks to release trapped air and fill pump and suction pipe completely with fluid
	Excessive suction lift	Check pump inlet for clogging etc. causing excessive friction head
	Excessive discharge head	Check that valves are open
		Check piping for obstructions or blockage
		Check total head
	Speed too low	Check that pump rev/min is consistent with manufacturer's recommendations
	Pump clogged	Check that impeller is not clogged
	Wrong direction of rotation	Check that pump is running in the correct direction
	Vapour lock	Bleed suction pipe to clear air lock
		Check that suction pipe is properly submerged
	Relief valve not properly adjusted	Check adjustment, check for dirt on valve seat
	Air leak	Check seals, check line(s) for air leaks
Low delivery	Air leaks	Check suction piping and pump for air leaks
		Check pump gaskets
	Vapour lock	Check NPSH and fluid temperature to ensure that liquid in suction line is not 'flashing'
	Low NPSH or damage	As above & also check suction pipe, foot valve etc
	Clogged strainer(s)	Check and clean if necessary
	Excessive inlet friction	Suction line too small, or too many fittings adding fluid friction
	Relief valve incorrectly set or jammed	Check and adjust as necessary
	Excessive system back pressure	Reduce system friction by re-design
	Worn impeller	Inspect and replace if necessary
	Worn wear rings	As above
	Wrong direction of rotation	Check against manufacturer's specification
	Construction in suction line	Check that foot valve size is adequate (if fitted)
		Check for other possible obstruction
	Wrong pump size	Check that pump is adequate for the job
	Poor suction	Check suction pipe is properly submerged and in best position

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TABLE 2 - Reciprocating Pumps - Fault-finding

Fault	Cause	Remedy or Action
Low delivery (Cont.)	High fluid viscosity	Check that fluid viscosity is consistent with anticipated performance
	Excessive fluid temperature	Reduce speed and/or delivery, decrease suction head
	Speed too low	Check operating rev/min against specification for pump performance
Over-heating	Stuffing box over-heats	Check that packing is not too tightly or badly fitted
		Check packing lubricant (where possible)
		Check that packing is consistent with manufacturer's specification
		Check cooling flow (where applicable)
	Bearings over-heating	Check oil level or lubricant condition
		Check if correct lubricant is being used
		Check bearing for misalignment or excessive tightness
		Check fitting and condition of oil seals
		Check that operating speed is not excessive
	Fluid too viscous	Reduce fluid viscosity (eg by heating)
	Excessive pressure	Reduce pump speed, increase delivery line size(s)
Vibration and noise	Cavitation	Check pump operating conditions
	Excessive fluid viscosity	Check product suitability
	Entrained air	Check for air leaks
	High vapour pressure fluid	Check product/pump suitability
	Improper pump assembly	Check and rectify
	Unbalanced impeller	Check that impeller is not damaged or clogged
	Misalignment	Check alignment with driver
	Non-rigid mount	Check mounting for rigidity
	Bent shaft, faulty bearings	Check and replace if necessary
	Pump wear	Strip down and check for wear
	Relief valve chattering	Re-adjust, repair or replace as necessary
Excessive wear	Misalignment	As above
	Out-of-balance	As above
	Non-rigid mount	As above
	Bent shaft	As above
	Lack of vibration	Check quantity and quality of lubricant
	Dirt in pump	Use filter to remove
	Corrosion	Check that pump materials are compatible with fluid being handled
	Too high operating speed	Check against manufacturer's recommendations for fluid viscosity
	Operating pressure too high	Reduce speed or pressure, eg change in system
	Abrasives present in fluid	Check product/pump suitability
Pump requires excessive power	Speed too high	Check against recommended rev/min
	Misalignment	Check alignment of pump and driver, also foundations
	Internal friction	Check for rubbing contact, clogging etc
	Tight bearings	Check bearings and packings (bearing temperature will be a clue)
	Lack of lubrication	Check quantity and quality of lubricants
	High fluid viscosity	Check that fluid viscosity is not too high for economic handling

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TABLE 3 - Reciprocating (Piston) Pumps - Fault-finding

Fault	Cause	Remedy or Action
No discharge	Not primed	Prime
		Open vents on discharge side to release trapped air and leave open until all air is discharged
	Excessive suction lift	Reduce suction lift or reduce suction friction with larger diameter pipe or eliminate bends etc
	Air leaks	Check system and eliminate air leaks by sealing etc
	Vapour-bound	Check fluid temperature and vapour pressure - fluid temperature may be too high, or suction lift excessive for fluid temperature
	Blockage	Check for blockage in suction pipe, foot valve or strainer
		Check pump suction valves
	Deterioration	Check suction valves, piston packing, piston rod packing, worn valves or badly scored cylinder
Low discharge pressure	Low steam pressure	Check for obstruction, leak or partially closed valve in steam system
	Tight packing	Loosen gland until leakage is apparent
	Excessive backpressure	Check that pump is not operating against excessive system head
	Deterioration	Check cylinder bore for wear, also condition of piston packings and valves
Pump stops or hesitates	Intermittent steam supply	Check for blockage etc
	Valve trouble	Check for excessive valve wear and leakage
		Check that valve timing is correct
	Excessive back pressure	Check that system head is not excessive
Variable delivery	Air leaks	Check system for air leaks
	Misalignment	Check alignment of pump and possible distortion due to unsupported piping connected to pump cylinder
	Excessive suction lift	As above
	Vapour-bound	Reduce fluid temperature, or reduce suction lift
	Tight packing	Loosen gland
	Excessive speed	Check that operating speed is consistent with specification
Pump short strokes	Excessive cushioning	Adjust cushioning valves to obtain stroke
	Worn valve	Check valve for leakage, re-face as necessary
	Entrained gas	Modify suction intake as necessary
	Incorrect valve timing	Check against specification and adjust as necessary
	Worn bore	Replace liner, or re-bore and fit oversize piston
Piston short-strokes	Excessive cushioning	Adjust cushioning valves to obtain correct stroke
	Worn valve	Check valve for leakage, re-face as necessary
	Entrained gas	Modify suction intake as necessary
	Incorrect valve timing	Check against specification and adjust as necessary
	Worn bore	Replace liner, or re-bore and fit oversize piston
Piston over-strokes (hits head)	Cushion valves	Close down as necessary to reduce stroke
	Piston leakage	Replace piston packing, replace worn liner or re-bore cylinder
	Valve leakage	Check valves on liquid head for leakage, re-grind or re-set if necessary
Excessive wear	Misalignment	Check alignment
	Bent piston rod	Check for straightness
	Worn bore	Replace liner or re-bore
	Fluid	Check that pump is compatible with fluid being handled

In many designs of pump intended for severe service conditions, provision is made for easy inspection, removal and replacement of worn parts without completely stripping down the pump, thus simplifying maintenance and making if both logical and economic to attend to maintenance at frequent intervals.

The only reason that really justifies shut-down and complete dismantling of the pump for inspection and overhaul is a marked loss of performance. If this is suspected, the pump can first be tested to establish if head, capacity or power input figures have deteriorated and whether remedial action is needed.

Reciprocating Pumps (Direct-Acting)

Steam pumps are generally trouble-free in operation and require little attention other than routine lubrication. Gaskets and packings will, however, require periodic replacement and maintenance will be required to correct for mechanical wear etc. Disassembly is usually straightforward and a specific procedure is usually detailed in the manufacturer's instruction manual.

Power-driven reciprocating pump maintenance is largely confined to checking the valve condition together with periodic attention to seals or packings. Valve seats may be re-ground, re-faced and ground, or replaced and ground in, depending on the severity of the wear. Operating time before such attention is required will vary widely with the type and design of pump and the service conditions.

It is good practice to check the valves on a new pump after three months' service unless there is some indication that earlier attention is needed. After that, maintenance periods can be based on experience.

Rotary Pumps

Rotary pumps in general have a minimum of moving parts and porting rather than valve systems, hence maintenance is normally held to a minimum and is largely confined to inspection for wear, corrosion or material defects, together with keeping the seals in good condition.

Disassembly normally follows a logical sequence when individual parts may be inspected for condition and wear, and clearance is checked against permitted tolerances. Excessively worn or defective parts should be replaced. Where corrosion is also present, it is advisable to check the material specifications against the liquid being handled as a replacement part of a better material may be available.

There may be specific instructions for disassembly, eg a spindle should be withdrawn in one direction only to avoid damage to a seal. The manufacturer's instruction book will, therefore, be the primary guide for maximum permissible wear on individual components.

The performance of many rotary pumps, particularly of the lobe rotor and multi-screw types, depends on accurate timing and the maintenance of prescribed clearances between the rotating elements. Any deviation from such settings normally results in a marked reduction in pump life and loss of efficiency. The importance of periodic timing and clearance checks is also emphasised.

In vane pumps, the principal wear is on the vanes themselves and the liner or casing on which they rub. With sliding vanes replacement is usually a straightforward matter. In some designs, it is possible to reassemble a worn vane the other way round and so double its effective life.

With swinging vanes, the shape of the pivoted portion of the rotor is such that a substantial degree of wear can take place without interfering with the sealing efficiency. There will, however, be a limit to the amount of wear which can be taken up purely by geometry and once this is exceeded, it will be necessary to replace the vane. With both types, vanes may usually be replaced merely by removing the cover plate or head plate, leaving the rotor in position.

Lobe-Rotor Pumps

Lobe-rotor pumps are precisely made machines; undue force must never be used during servicing. Be especially careful not to damage the means of alignment between rotor case and gear case. Ensure that sealing surfaces of mechanical seal rings are not scratched or damaged in any way. If in doubt, obtain correct fitting length from manufacturer.

For shut-down and maintenance, isolate the pump from electrical and hydraulic supplies. Do not allow the product to solidify in the pumping chamber or on shaft sealing surfaces. Product wetted parts can often be cleaned with hot water and detergent.

It is advisable to hold components of the following types in stock. Quantities depend on pump design, service conditions and stocking policy:

a) O-ring seals - pump head, shaft sleeve, front valves, mechanical seals, port connections, gear case.

b) Oil seals and joints - gear case.

c) Glands - packing sets, preferably pre-formed rings.

d) Mechanical seals - rotating and stationary sealing rings, springs.

e) Transmission - flexible coupling parts, belts, gearbox parts.

f) Miscellaneous - lubricating oil, relief valve springs, fasteners.

Condition Monitoring

The terms predictive maintenance, or machine diagnostics, are often used to anticipate pump failure and determine a probable cause. Incorrectly stating the problem is one of the most common errors in troubleshooting pumps. The primary advantages of predictive maintenance are:

- Reduced maintenance
- Increased machinery availability
- Improved plant safety

Condition monitoring plays an important role in avoiding pump failure. In the case of centrifugal pumps, three areas of monitoring can be distinguished:

1) Monitoring the mechanical components
2) Monitoring the shaft seal
3) Monitoring the hydraulic components

Automatic monitoring has become more widely used, particularly in fields where safety is a major factor. Comprehensive condition monitoring in the form of documental reports and data should be kept to help identify recurring problems and determine optimum timing for scheduling preventative maintenance.

Tracking the mean time between repair (MTBR) for all pumps serviced can improve reliability and identify troublesome units.

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TABLE 4 - Rotary Pumps - Fault-finding

Fault	Cause	Remedy or Action
No discharge	Not primed	Prime to fill pump
	Excessive suction lift	Reduce suction lift or reduce friction in suction side with large pipe
	Air leaks	Check and rectify, check gaskets
	Blockage	Check adjustment and setting
	Excessive wear	Check components for wear against manufacturer's permitted tolerances
	Wrong rotation	Check that pump is being rotated in the correct direction
	Insufficient speed	Check that pump is running at rated speed
Low discharge pressure or reduced capacity	Insufficient speed	As above
	Wrong rotation	As above
	Excessive suction lift	As above
	Air leaks	As above, check gasket particularly
	Air entrainment	Re-position suction inlet
	Relief valve or bypass valve	Setting may be too low. Check and re-set
	Excessive wear	Check as above
Excessive noise	Misalignment (where applicable)	Check alignment of driver and pump and drive connection
	Internal damage	Bent or broken rotor
	Unbalance	If suspected, check rotor for static and dynamic balance
	Air entrainment	Re-position suction inlet
	Air leaks	Check and rectify
	Cavitation	Check against causes of cavitation
	Excessive pressure	Relief valve set too high, adjust to correct setting consistent with pump rating
	Deterioration	Check for excessive wear or clearances on components
Excessive discharge pressure	System pressure	If system pressure is too high for pump rating, a larger pump will have to be used, when some relief may be possible
	Relief valve or bypass valve	Check and re-set relief valve for correct pressure
	System throttled	Discharge valve may be partially closed or system partially blocked
Excessive wear	Abrasive liquid	Check that pump is suitable for handling liquid if abrasive solids are present, or check that filter or strainer used is adequate
	Distortion	Pipework loads transmitted directly to the casing may cause distortion
	Excessive pressure developed	See above
	Excessive speed	Check that speed is consistent with pump specification for viscosity of liquid handled
Excessive input power required	Damage	Check for bent or damaged shaft etc
	Excessive pressure	As above
	Excessive fluid viscosity	Check speed rating against actual viscosity of fluid, reduce speed for higher viscosities
	Excessive speed	Check against pump rating for fluid viscosity handled
Pump overheats	Relief or bypass valves	Check that settings are correct
	Excessive speed for fluid handled	Check that speed is consistent with rating for fluid viscosity
	Excessive pressure	As above
	Discharge throttle	Looped flow through relief valve will cause heating, may be relieved by separate relief valve discharging to tank

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TABLE 5 - Lobe-Rotor Pumps - Fault-finding

No discharge	Under capacity	Irregular discharge	Prime lost after starting	Pump stalls when starting	Pump over-heats	Motor over-heats	Excessive power absorbed	Noise and vibration	Pump element wear	Excessive gland/seal wear	Product loss through gland	Seizure	Cause	Remedy or Action
x													Incorrect direction of rotation	Reverse motor.
x													Pump unprimed	Expel gas from supply line and pumping chamber and Introduce liquid.
x	x	x	x					x					Insufficient NPSH available	Increase supply line diameter and increase static suction head. Simplify supply line.
	x	x	x					x					Product vapourising in supply line	Configuration & reduce length. Reduce speed. Decrease product temp., check effect of increased viscosity on available permitted power inputs.
	x	x	x					x					Air entering supply line	Remake pipework joints. Adjust or repack gland.
x	x	x	x					x					Gas in supply line	Expel gas from supply line and pumping chamber and introduce liquid.
	x	x	x					x					Insufficient head above supply vessel outlet	Raise product level. Lower outlet position, increase sub-mergence of supply pipe.
x	x	x	x					x					Foot valve/strainer obstructed or blocked	Service fittings
			x	x	x	x	x	x					Product viscosity above rated figure	Decrease pump speed. Increase product temperature
	x												Product viscosity below rated figure	Increase pump speed. Decrease product temp.
	x				x			x	x			x	Product temperature above rated figure	Cool the product/pumping chamber.
				X		X	X						Product temperature below rated figure	Heat the product/pumping chamber. (Check with pump maker).
								x	x	x	x	x	Unexpected solids in product	Clean the system. Fit strainer to supply line.
	x			x	x	x	x	x	x			x	Delivery pressure above rated figure	Check for obstructions. Service system and revise to prevent problem recurring. Simplify delivery time.
					x	x	x			x		x	Gland over-tightened	Slacken and readjust gland.
	x	x	x					x			x		Gland under-tightened	Adjust gland.

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(TABLE 5 - Lobe-Rotor Pumps - Fault-finding (Cont.)

No discharge	Under capacity	Irregular discharge	Prime lost after starting	Pump stalls when starting	Pump over-heats	Motor over-heats	Excessive power absorbed	Noise and vibration	Pump element wear	Excessive gland/seal wear	Product loss through gland	Seizure	Cause	Remedy or Action
											x	x	Gland flushing inadequate	Check that fluid flows freely into gland. Increase flow rate.
		x	x			x	x	x					Pump speed above rated figure	Decrease pump speed.
	x												Pump speed below rated figure	Increase pump speed
					x	x	x	x	x			x	Rotor case strained by pipework	Check alignment of pipes. Fit flexible pipes or expansion fittings. Support pipework.
	x												Belt drive slipping	Re-tension to maker's recommendations.
					x	x	x	x					Flexible coupling misaligned	Check flange alignment and adjust mountings accordingly.
								x					Insecure pump/driver mountings	Fit lock-washers to slack fasteners and re-tighten.
					x	x	x	x	x			x	Shaft bearing wear or failure	Refer to pump maker for advice and replacement parts.
				x	x	x	x	x	x			x	Worn unsynchronised timing gears	Refer to pump maker for advice and replacement parts.
					x	x	x	x				x	Gear-case oil quantity/quality incorrect	Refer to pump maker's instructions.
				x	x	x	x	x	x			x	Metal-to-metal contact of pumping element	Check rated and duty pressure. Refer to pump maker.
	x												Worn pumping element	Fit new components
x	x				x								Front cover relief valve leakage	Check pressure setting and readjust if necessary. Examine and clean seating surfaces. Replace worn parts.
	x							x					Relief valve chatter	Check wear of sealing surfaces guides etc, replace as necessary.
	x							x					Relief valve incorrectly set	Readjust spring compression. Valve should lift about 10% above duty pressure.

DIAGNOSIS WILL BE GREATLY ASSISTED BY TAKING ON-STREAM PRESSURE READINGS AT THE PUMP'S INLET & OUTLET PORTS.

Mean Time Between Repair (MTBR)

Mean time between repair is calculated using the following formula:

$$MTBR = \frac{(P-NR) \times \text{number of months data}}{\text{Number of repairs}}$$

Where:

P	=	Total number of pumps in population
NR	=	Number of pumps that have installed spares such that one is normally not running
Repair	=	An event that makes the pump unavailable for pumping

Average pump life can be quite an accurate measure of pump reliability.

Before a pump is taken out of service, as much hydraulic performance data as possible should be obtained. This can be achieved by accurately measuring flows, temperature, pressure, specific gravity, viscosity etc around the pump and by consulting historical data and other useful information about its operating condition.

Simple vibration monitoring and analysis can be an accurate and rapid method for detecting mechanical problems in a pump.

Three basic measurements involve:

1. Measuring the bearing cap or casing vibration.
2. Measuring the shaft vibration relative to the bearing.
3. Measuring the absolute shaft vibration.

The objective in monitoring rotating machinery vibrations is to determine when the rate of change in vibration level begins to change.

Sealless pumps generally require more monitoring than mechanical seal pumps. Temperature measurement, bearing condition monitoring, low current trips (for cavitation protection) are all useful for magnetic drive pumps. Canned motor pumps also require liquid level monitoring.

Some of the most common problems with pumps include misalignment, oil contamination, incomplete priming and the absence of detailed up-to-date spare parts records.

Pump Protection

In many cases, the reasons for pumping system failure are other than the pumping system itself. These include improper selection of the pump, improper handling of the system and improper selection of protective devices.

Protection for a pump falls into six broad categories:

1. Against phase failure and unbalanced supply
2. Against over-loading
3. Against dry-running
4. Against over-heating
5. Against moisture
6. Against under/over voltage

Typically, the selection of appropriate protective devices should take into account the following points:

a) It operates on the current sensing principle.
b) It senses the negative sequence components of the supply.
c) It offers protection against phase failure faults.
d) It offers protection against failure even at No-load conditions.
e) It offers protection against overloading according to the thermal-withstanding characteristics of the motor.
f) Dry running protection is not based on sensing the water level directly by a sensor but by means of indirect methods like sensing current, rpm or pressure.

Protective devices incorporating these characteristics will almost certainly lead to longer pump life.

The development of sophisticated electronics, computers, chemical analysis, lasers, vibration pick-ups, sonic measurements, ultra-sonics, and radio graphics have permitted the analysis and forecast of the life of any pump component so that opening up maintenance can be carried out at a reasonable period before expected failure, rather than at routine times.

There is really no point in stripping of a machine if it is certain that it is operating satisfactorily.

It is probable that the cost of monitoring will amount to less than the costs of routine maintenance disassembly, particularly if predictive maintenance is employed.