BOOKLET

O&M Handbook
Water Supply Services

O&M of Pumps, Drives and Pump Stations

November 2009

O&M Handbook for Water Supply Services

The series of five handbooks on operation and maintenance forms part of a programme to build the operational and technical capacity of Northern Cape municipalities, to improve and extend service delivery and maintain infrastructure and other assets. This handbook is intended as a practical, hands-on guide for technical staff, trainees and others involved in the areas of water supply services.

The ultimate purpose of the programme and handbooks is to build municipal capacity to improve and extend service delivery, particularly to communities whose basic needs have not yet been adequately met, as an essential contribution to creating a better life for all.

This ***O&M Handbook for Water Supply Services*** consists of 14 separate booklets including an introductory booklet. Though each booklet is part of the whole handbook, it can be used on its own.

November 2009

O&M
NORTHERN CAPE

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Introduction to Ways of Pumping Water

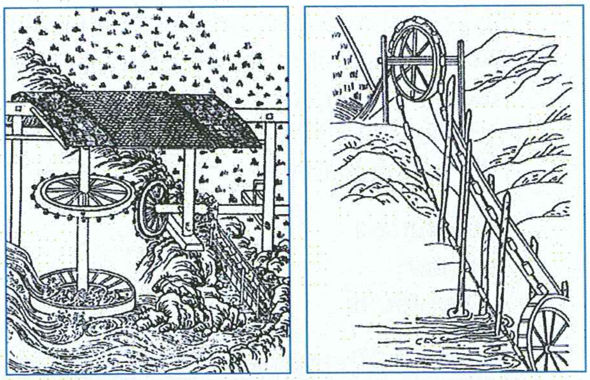
A pump is a machine or mechanical device that draws a fluid into itself through an inlet port and forces the fluid out through a discharge port by means of a roto-dynamic or reciprocating movement.

A pump may serve to move liquid, as in a cross-country pipeline, to lift liquid, as from a well or to the top of a tall building, or to put fluid under pressure, as in hydraulic systems. These applications depend predominantly on the discharge characteristics of a pump. A pump may also serve to empty a container, as in a vacuum pump or a sump pump, in which case the application depends primarily on its intake characteristics.

As the terrain where water supply systems are installed is often undulating, we need pumps and pump stations to lift water uphill in some places to reach the whole community. A pump is a mechanical wonder that enables us to make water flow uphill.

Ancient inventions

The earliest evidence of pump-like devices is in a Babylonian text from 700 BC. These devices were powered by humans or animals, and lifted water rather than actually pumping it. Similar devices were used in ancient Egypt, featuring a pair of gear-wheels. A version of this kind of device was used in Roman times, with pots fixed to the chain, which, as they passed over the top pulley, tipped the water out. This was known as a chain pump and the Chinese had several versions of this basic type. Chain pumps were also used in European mines and dockyards during the Renaissance (1400–1600). Pumps were commonly used on ships to pump water out of the bilges, and in the nineteenth century for low-lift irrigation purposes.



Examples of Chinese Chain Pumps
Illustration Internet

A double-action pump

The illustration shows a bronze double-action pump, from the Roman Empire in 200 AD. The pump has two pistons (a) that are lifted up and pushed down in the two cylinders (c) by a handle (b). There are non-return valves (d) at the bottom of the cylinder into which water is sucked when the piston is lifted. When the piston is pushed down, water is pushed into the connecting pipe (e) and via another non-return valve (f) out into the middle pipe (g).

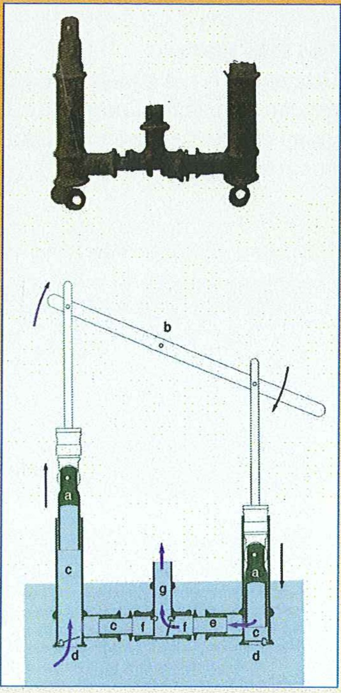
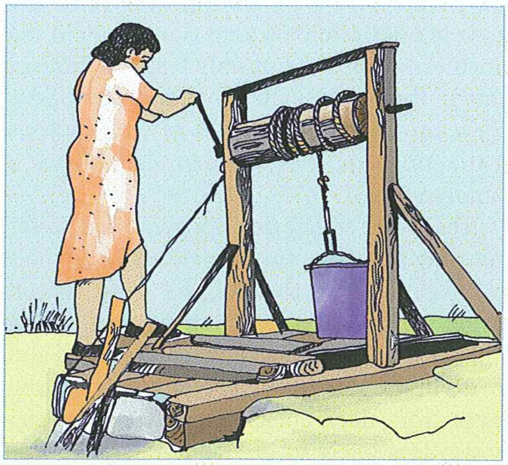


Illustration from 'Vatten' by Staffan Michelson

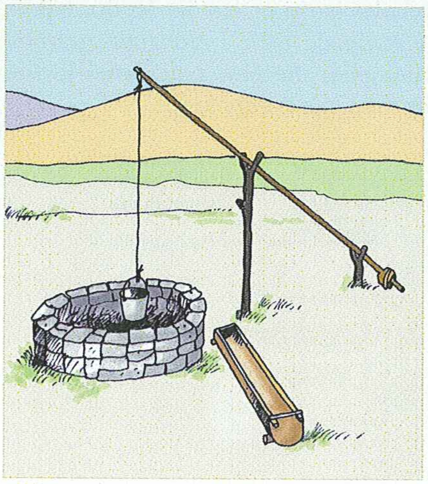
Water lifting methods and hand pumps

The simplest way of lifting water before pumps were invented, was to lower a bucket at the end of a rope into the shallow well. The next development was the *rolput*, as it is known in Afrikaans. This consisted of a wooden roller on wooden or iron legs, which stood over the mouth of the well. The rope with the bucket was attached to the roller, which was turned by a cranked handle at one or both ends by one or two persons.



Rolput

Another early water lifting device was the *wipput*, which consisted of a long pole pivoted near the centre in the fork of an upright post. The bucket hung on a rope from the end of the pole over the well, and a counterbalancing stone was attached to the other end.



Wipput

To provide a more continuous water supply in the olden days, a favourite machine was the animal driven *bakkiespomp*, the bucket pump. The concept originated in India and this 'pump' came to South Africa (via England) in the late 1880s. Iron buckets were attached to two parallel drive chains running on large wheels mounted over the well. The buckets filled with water when they dipped into the well (again wells had to be shallow) and when they reached the top of the wheel they emptied the water into a basin from which the water poured into a small channel. One of the wheel shafts had a horizontal cog driven by a pinion on a vertical shaft. A pole was attached to the top end of this shaft, and a donkey or mule yoked to the pole drove the pump by walking around it. A bucket pump harnessed to a donkey statue can be seen at the Kalahari Museum in Upington *(see photo below)*.

Hand pumps are used in rural communities around the world, but have limited capacity, as they depend on human energy to drive them. Where the water is very deep, a human being cannot supply sufficient power to drive the pump. Hand pumps are thus restricted to shallow boreholes (50 m or less in depth), unless they are equipped with a reduction gearbox which multiplies the power delivered to the pump for the same energy input.

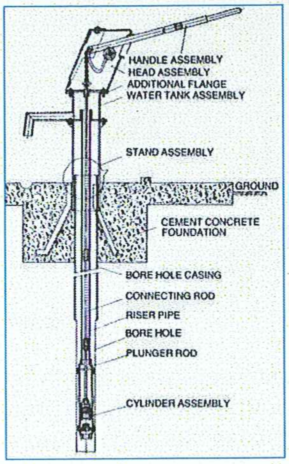
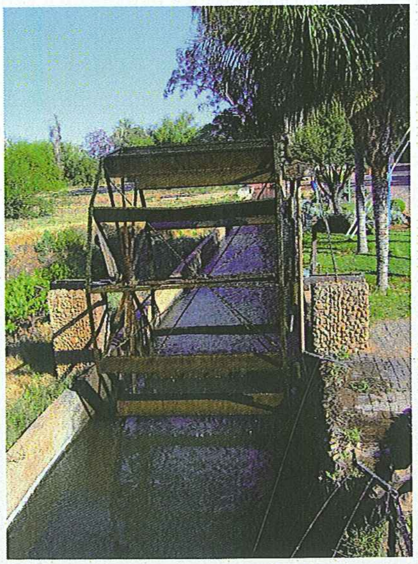


Diagram of a India Mark 2 Hand Pump

Illustration: DWAF

In Keimoes and Kakamas there are examples of another old water lifting device, the water wheel. The water wheel concept has been used on the Nile for some four thousand years. It was introduced in Northern Cape in the early years of the 19th century. Water wheels use the flow of water to lift some of it into an irrigation channel. Four water wheels in Kakamas are national monuments.



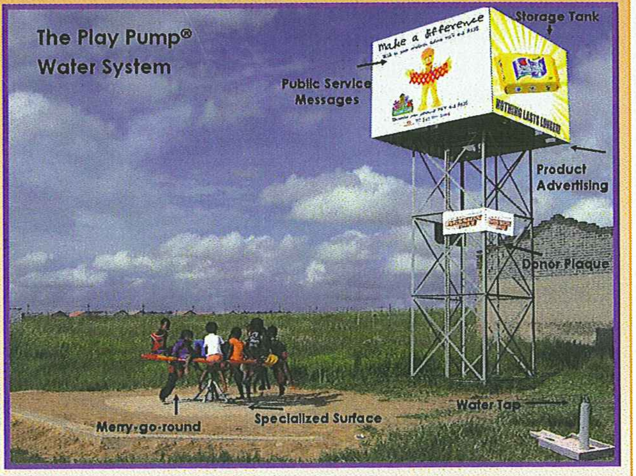
Water wheel

learn more about

The Play Pump

However, it is not always hard work to pump water. A South African invention, known as the Play Pump, connects a hand pump mechanism to a merry-go-round, so that children pump the water as they play.

Diagram showing a Play Pump installation



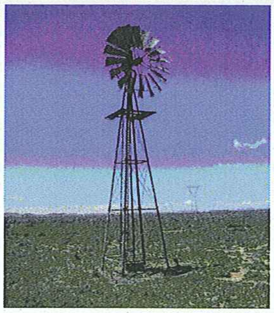
courtesy Mark Melman, Roundabout Outdoor (Pty) Ltd
www.playpumps.org

Wind energy

Wind and sun energy are mainly used to power pumps on borehole installations. The agricultural industry is particularly reliant on groundwater, with water traditionally pumped from boreholes by wind pumps. You don't need to drive far in South Africa to encounter a 'windmill', or *windpomp* as it is known in Afrikaans.

There is a unique open air museum displaying wind pumps and other interesting old pumps and water lifting devices in the town of Loeriesfontein near Carnarvon in the Northern Cape, one of only two such museums in the world. (The other is in the USA). There are 28 different types of wind pumps at the museum, some of them dating back a hundred years!

The water lifting devices presented so far can only lift water from open water or shallow wells. The arrival of the wind driven piston pump had a great impact on farming and providing potable water to dwellings and towns in the Northern Cape, as it could pump water from deep boreholes, where the water is also less likely to be contaminated. Some



Wind pumps come in different types and sizes.
Top photo unknown

wind pumps went down as much as 60–100 metres, and in rare cases as much as 150 m, a far cry from the original shallow wells of two to three meters depth.

Wind pumps usually have either a plunger-type positive displacement pump or a rotating progressive cavity, positive displacement-type pump. In the case of a plunger-type pump, the rotational energy of the wind vanes is converted to a reciprocal (up and down) motion by turning a crank in the head of the wind pump. When a rotating progressive cavity-type pump is used, the rotational energy of the wind vane's horizontal shaft is converted by means of a 90° gearbox which drives a vertical shaft to power the progressive cavity pumping element. The gearbox can also increase or decrease the revolutions, depending on the application requirement.

The discharge rate of a wind pump depends on wind speed, as well as the pumping head (the vertical distance which the water must be lifted), and also the friction loss of the pipes through which the water is conveyed. However, their reliability is low as they only operate when there is sufficient wind - at least 2,5–3 m/s or more, for at least 60 % of the time is necessary for a wind pump to be considered. Even if 60 % operational time is possible, the standard of service is low, unless several days of storage is provided.

Though wind pumps also have the disadvantage of a high capital cost, they require very little maintenance apart from regular greasing of the bearings and gearbox. They also require a functional furling, braking and reefing mechanism to protect the pumping mechanism from serious damage during strong, gusty winds. Given these limitations, they are not often suitable for supplying water to communities, though many municipalities use them to provide water on commonage for livestock watering and small-scale irrigation schemes. However, wind pumps are very environmental friendly as they do not use any fossil fuels. Their energy input is local and free!

learn more about

Wind loading on mast structures

The wind flow around buildings and structures is a complex phenomenon. Small changes in shape, surface irregularities, and vertical and horizontal changes in wind velocity all have significant effects on the wind flow around a structure. The loads imposed on a structure by the force of the wind are thus dynamic, and can vary within relatively short periods of time. For simple structures and low buildings, the effects of wind loading are compensated for by designing for the worst possible wind gust (which has a low probability of occurring), and considering this load as if it were a static load.

On tall, slender structures such as masts and high-rise buildings, this method cannot be applied. Such structures require scale model studies in a wind tunnel, where winds of various speeds can be simulated and measured under controlled conditions, and the effects on the structure can be measured and analysed using finite element analysis methods. Winds can create both surface pressures and vacuums, depending on the shape of the structure and the direction of wind over it.

The design of mast structures is a complex task and specialist structural engineers should be employed when such structures are planned, to ensure that the effects of wind loading have been taken into account in the design, to ensure a safe and reliable structure.

"We should go back to wind pumps

– a story from Emthanjeni Municipality

There is a famous riddle in Northern Cape: Wherever you go, you see them; whenever you see them, they go!

This somewhat over-exaggerates the reliability of wind pumps, but Chris Hendricks is a great fan.

– For actual service rendered, wind pumps are remarkably cost-effective, he says.

– Once you have installed them correctly, the maintenance and upkeep is minimal for many years. If we could only go back to wind pumps for the town water supply, it would save us a lot of problems, jokes Chris.

Chris is the Water Supply Services Supervisor at Emthanjeni Municipality, based in De Aar. The technical department maintains more than 20 wind pumps on municipal commonage, which supply water to small farms for livestock watering and irrigation.

Scheduled preventative maintenance

– We have Climax, Southern Cross and Aermotors pumps. The oldest is more than 50 years old, says Chris.

– Our preventative maintenance programme includes two visits per year to each of the pumps. We check the tower and its foundation, and the pump rods. Sometimes we replace a worn piston or rusty pipes. We check the wheel and its blades, and the tail. In the gearbox casing we check that the gears are not worn and are properly in place, and we change the bushes and top up the oil if necessary. Every two to three years we change the oil. Occasionally we have to re-drill a borehole that has caved in, or repair a wind pump that has been toppled by a strong wind. We still have no problems getting spare parts.

– One very important thing is that the brake is pulled when the wind is too strong, to prevent damage to the pump. We have agreements with the local farmers to do this, and to look after their 'own' pumps, concludes Chris.

Chris Hendricks at one of the wind pumps that his team maintains.

Maintaining a wind pump – one staff member secures the brake, while the other climbs up to check the gearbox.

South African ingenuity

The earliest wind pump described or illustrated in South Africa is from around mid 1800 in Saldanha Bay. The earliest imported wind pump that we know of was one in Hopetown. It was made of wood and imported from U.S.A. in 1874.

Several South African companies were agents for wind pump manufacturers in the USA, UK and Australia. During the Second World War importing was impossible and some South African firms began to manufacture the same wind pumps under license. Most wind pumps were geared and self-lubricating, and only required an oil change every one or two years.

Over the years, many South African engineers and others invented and produced a variety of wind pumps. Names such as Nimric, Buffalo, Gearing, Springbok and others on the tails of old wind pumps remind us of these early pioneers. A.L. Schoombee was a South African inventor who presented a model of a wind-driven rotor mono-pump in 1980. It was later manufactured by Midkaap Ingenieurswerke in Middleburg, and marked as the M&S Rotor Windpomp.

But the best-known wind pump, found all over the country, is the Climax, manufactured in Vereeniging by Stewart and Lloyds. Another well-known make is the Southern Cross, manufactured by Southern Cross Industries in Bloemfontein.

Solar powered pumps

Solar powered pumps have of late become a feasible option, using photovoltaic solar panels to generate electricity, sometimes with battery backup. They are ideally suited to remote installations in provinces with an abundance of sunshine, like the Northern Cape. South Africa has very high solar radiation levels. Solar powered pumps produce a regular supply of water, but depending on the type of pump used, are limited at this stage to heads and quantities of water similar to those of hand and wind pumps, which they can therefore replace. The initial costs of solar pump installations are high, but overall pumping costs are very economical in the long run.

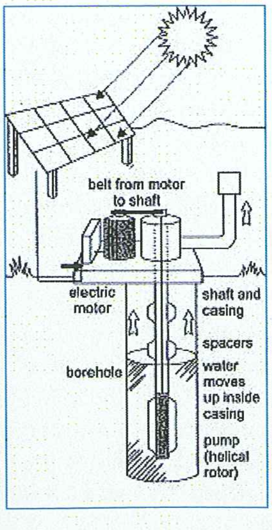
When compared to diesel-driven pumps, a lifecycle cost analysis over 20 years shows that diesel pumps are roughly four times more expensive, assuming the following

- The initial capital investment for a solar installation is about twice that for a diesel installation with similar pumping capacity.
- When replacement of equipment is considered, the lifecycle of a diesel-driven pump in such an application is 5 years, while a similar sized solar powered pump has a lifecycle of 7 years. When this is taken into consideration, the cost of a diesel pump already exceeds that of a solar pump.
- The maintenance cost of a diesel pump is twice that of a solar pump. When total lifecycle costs are compared at this point, the diesel pump is already double the cost of a solar pump.
- The operational costs of a diesel pump are roughly ten times higher than the operational costs of running a solar pump.
- Over a 20 year period, a solar pump will cost on average around R130 000, while the all inclusive cost for a similar sized diesel pump will be about R740 000.
- When the Unit Water Cost for these pump is calculated (for a pump delivering 8 m^3/day at a total head of 120 m), the cost for a solar pump is in the order of R5/m^3, while the cost for a diesel pump is in the region of R18/m^3.

It is thus clear that solar powered pumps are between 70 % and 90 % cheaper to own, maintain and operate over a 20 year lifecycle.

Photovoltaic solar panels convert solar energy into direct current (DC) electricity, which is regulated by a controller to an electrical output suitable for a DC pump motor. DC produced by a solar panel can also be converted to alternating current (AC) by means of a sine wave inverter to power an AC pump motor.

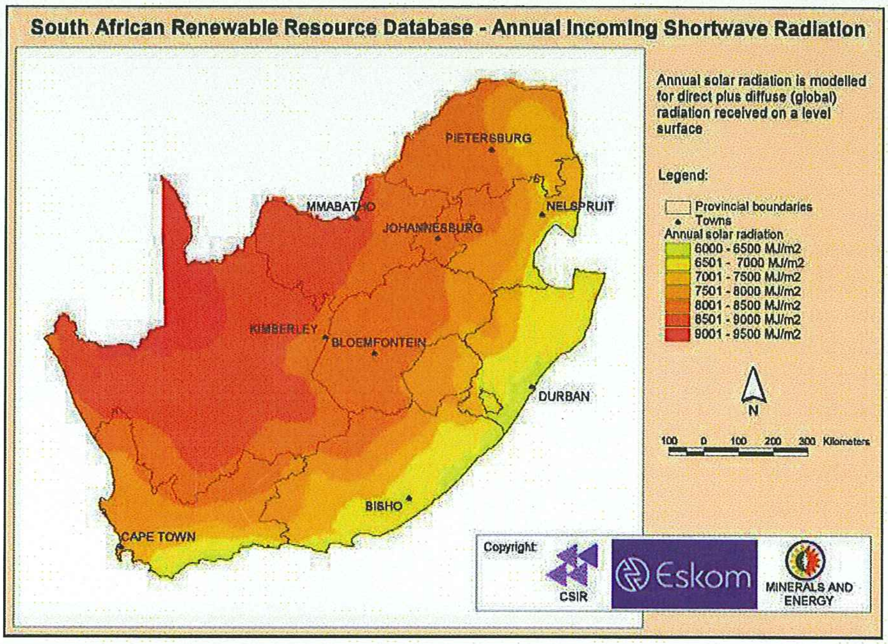
Although DC can be converted to AC, this is not advisable. In the first place, DC motors are up to 100% more efficient than AC current motors of similar size. This is largely due to the fact that DC motors have permanent magnets and do not use a portion of the electrical energy to induce the magnetic force required for rotation. With double the efficiency, you only need half the power for the same performance. Brushless DC motors are recommended for solar applications, as they are highly efficient, very reliable, and have low maintenance requirements.



A solar powered pump installation
Diagram: DWAF
Photo: Africon

Solar systems can be used to power both submersible pumps and centrifugal pumps for surface water applications.

Water is generally pumped into a reservoir and reticulated to households or community standpipes. The figure below illustrates the operating principles.



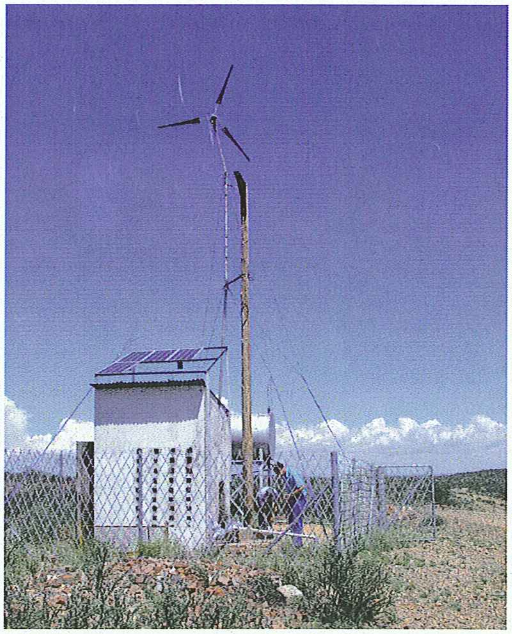
A Northern Cape is ideally situated for the use of solar power.
Map courtesy Escom

Engine-driven pumps

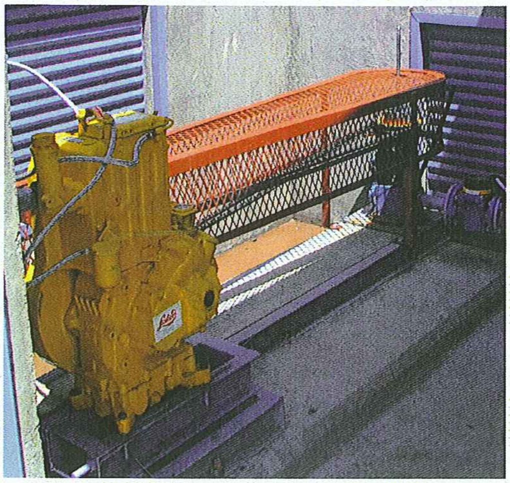
When a reliable source of water is needed it is not possible to rely on wind power, as there are very few places with constant all-year-round wind. Where there is no electricity supply available, diesel engines are often used to drive pumps, including in several rural water schemes not yet connected to the Eskom distribution network.

Petrol and diesel engines can be used, but diesel is more popular due to better fuel efficiency. However, petrol and diesel engines require much more maintenance and have higher energy input (fuel costs) than electric motors.

Diesel engines should be considered as the last option, as they are not nearly as efficient as electrical motors. They demand a constant supply of fuel and regular maintenance. Where diesel motors are operated 24 hours a day, they often need a complete overhaul at least twice a year. Depending on the size and type of engine, this can be an expensive exercise.



In Vanwyksvlei, some municipal production boreholes are equipped with submersible pumps, powered by a combination of solar and wind energy.

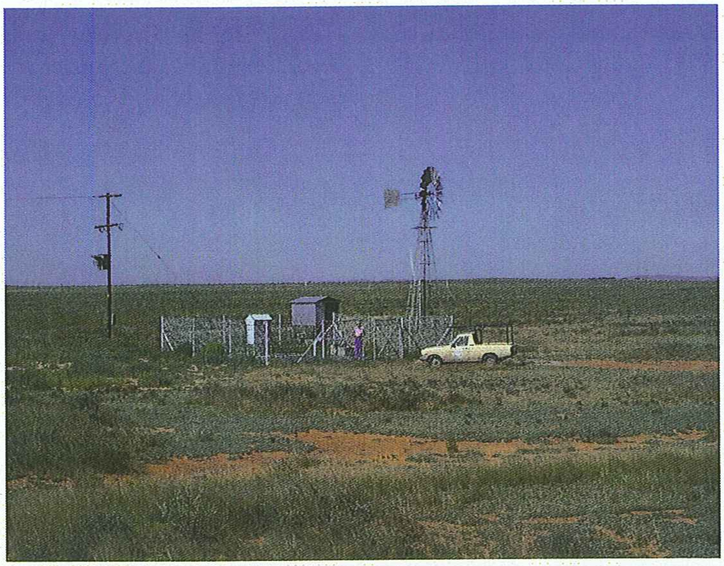


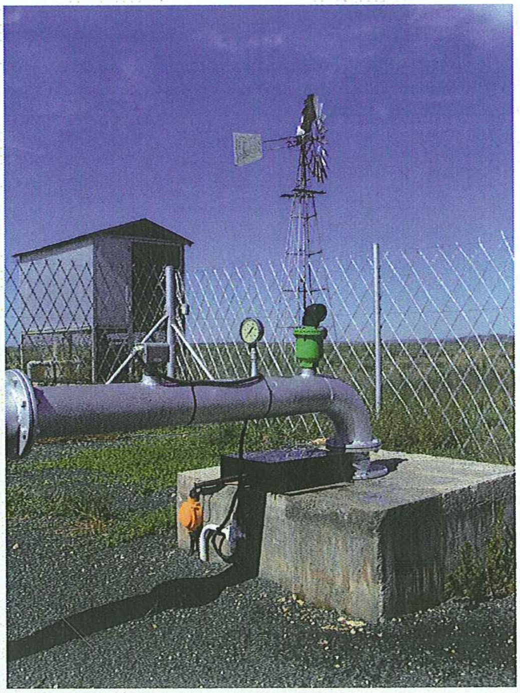
A diesel engine driven pump. Note the compulsory safety cage over the moving V-belts between the engine and the pump.

Diesel engines are preferred for these applications as they produce large amounts of torque at fairly low engine revolutions and are much more fuel efficient than petrol engines. In addition, diesel engines are suited to long hours of continuous running at constant speed, without ill effects. However, clean air and fuel filters and regular oil changes are critical for diesel engines. When run continuously, oil change intervals should not exceed 500 hours. When compared to electrical power on a kW to kW basis, the energy provided by diesel engines is four times more expensive than the equivalent electric energy. For this reason, pump stations are usually converted to electrical power when it becomes available.

Electrical motor driven pumps

If electricity is available near a pump station it is most economical to use it, as electric motors require much less maintenance than engines. Electrical motors must be correctly sized by the design engineer responsible for the installation. It is important to know that any changes to the pump impellor or rising main pipeline can increase the power required by a pump, and thus overload the existing motor.





In the Northern Cape Province, roughly 40 % of the population or 465 000 people living in 231 towns and settlements depend on groundwater pumped from boreholes. Most borehole pumps are driven by an electric motor, powered by the national grid.

There are actually three boreholes in the photo taken outside Hannover. The newly installed borehole is properly fenced, and has a submersible pump, controlled by a telemetry unit in the motor control centre (the white cabinet). Behind this modern borehole installation is an older borehole in a corrugated iron pump house. A much older borehole is powered by a wind-driven pump. Remember that each borehole installation must be regularly inspected by a senior operator or foreman, including the modern one controlled by the telemetry system.

Drives, Motors and Starters

In order to pump water from point A to point B we need energy to drive a pump, either from a motor, which may be a diesel engine or electric motor, or from some other direct source, such as the wind in the case of a wind pump.

Electric motors

These days almost all pumps are driven by electric motors, as these are most energy- and cost-efficient in terms of running cost and maintenance. Electricity in SA is generally supplied as three-phase alternating current at a voltage of 230/380 volts and a frequency of 50 hertz. There are three main types of electric motors

- Squirrel cage induction motors
- Asynchronous slip-ring motors
- Synchronous motors.

Synchronous motors are very costly but most efficient, having a power factor of 1,0, whilst other types of motors generally have a power factor of 0,8 to 0,9.

The size of a pump depends on how much water needs to be pumped, how high it must be lifted and how far it must be moved. This in turn determines the size of the electric motor.

Power output in kW	The average car delivers 75 kW of power
Motor speed or revolutions per minute (rpm)	Most motor car engines have a red line at 6000 revolutions per minute, while most motors that drive pumps run at 1450 or 2900 revolutions per minute
Potential difference in Volts	A household hair dryer uses 220 V, while most pumps are driven by electrical motors that run on 380 V (3 Phase)

Pump motor specifications comparison

Power required by the pump

The power requirement is calculated as follows, and is important as it will influence the municipality's monthly electricity bill.

$$P = \frac{\rho g Q H}{\eta}$$

P = Pump shaft Power
ρ = Density of pumped fluid = 1000 kg/m³ (water)
g = Gravitational Constant (m/s²)
Q = Plump Flow (m/s)
H = Total Head (m)
η = Pump efficiency (supplied by manufacturer)

Example

If you need to pump water at a flow of 80 ℓ/s to a higher reservoir 25 m high (head) and pump efficiency is 75 %, what would the power required be?

$$P = \frac{\rho g Q H}{\eta}$$

$$P = \frac{1000\,\text{kg/m}^3 \times 9{,}81\,\text{m/s}^2 \times 0{,}080\,\text{m}^3\text{/s} \times 25\,\text{m}}{0{,}75}$$

$$P = 26\,160\,\text{Watt}$$
$$P = 26\,\text{kW}$$

Note that all units include metres.

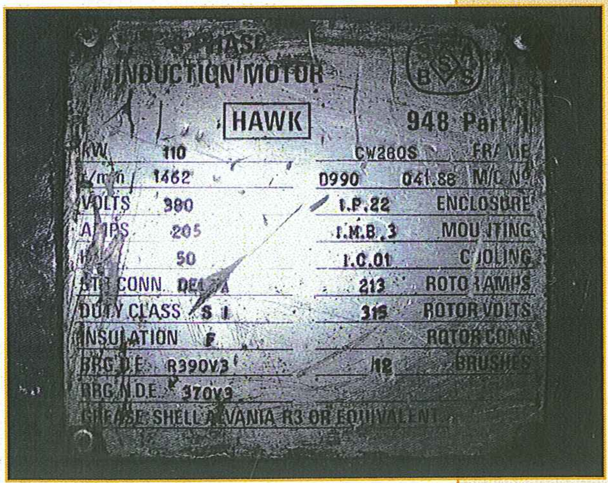
learn more about

Understanding a motor specification plate

The photo below shows a typical specification plate on an electric motor. It is good O&M practice to always keep the plate clean. The information on the plate is vital for planning of O&M, and must therefore also be kept in the technical department office, as part of the asset register. This is what the specifications mean

kW – 110 — the rated power the motor can provide
r/min – 1462 — rotational speed of the motor in revolutions per minute
VOLTS – 380 — indicates a three phase motor which requires 380 V to operate
AMPS – 205 — the maximum full load current of the motor
Hz – 50 — the frequency of the alternating current required to operate the motor
CONN — indicates whether the motor is connected in Star or Delta configuration
Duty Class S1 — indicates if the motor is suitable for continuous use
Insulation F — insulation class which relates to a maximum operating temperature where the insulation on the motor windings will not fail. Class F indicates a temperature of 155 °C.
BRG DE — the size of the drive-end bearing
BRG NDE — the size of the non-drive-end bearing
GREASE — specification of grease type required for lubrication
FRAME — the frame size – there are several standard sizes available for each motor size
ENCLOSURE IP22 — the degree of protection from dust and water ingress and impact

- MOUNTING — indicates if the motor is pedestal mounted, flange mounted, etc
- COOLING — indicates whether the motor is cooled by natural convection, forced convection or other methods of cooling.
- ROTOR AMPS — current on the rotor
- ROTOR VOLTS — rotor voltage
- BRUSHES — number of brushes on the motor



Total electrical power required

$$P_T = \frac{P}{\eta_m} \quad (kW)$$

P_T = Total Power required
P = Pump Shaft Power
η_m = Motor Efficiency (supplied by manufacturer) for example 90 %

Example

$$P_T = \frac{26\,kW}{0{,}90}$$

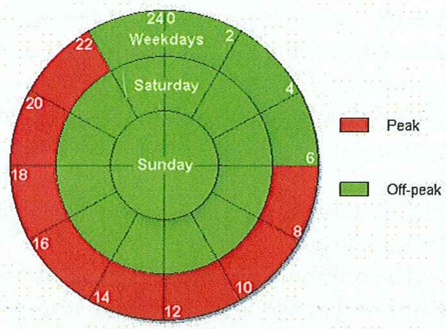
$$P_T = 28{,}88\,kW$$

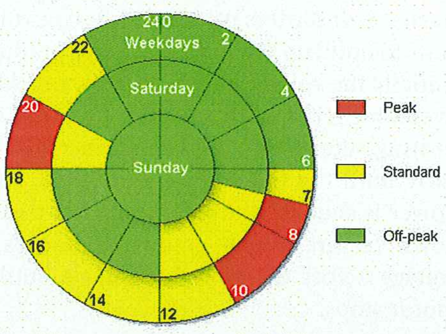
Because electrical motors are not supplied in 28 kW size, we will have to install a 30 kW motor.

Energy cost and the electricity bill

$$Energy = P_T \times t \quad (kWh)$$

P_T = Total Power Required
t = Time in hours





To link the formula to the electricity bill, multiply with the actual Eskom rate in rands and cents. Eskom has several initiatives to save large energy consumers such as municipalities money by offering a reduced electricity rate, if they consume electricity outside of peak periods. Programmes like 'Ruraflex' fer a reduction in energy cost if the municipality pumps outside of peak demand hours. For municipalities this is often not practical as the pumping hours are usually determined by the demand. If a municipality has sufficient storage to meet demand peaks, it may be possible to use this programme and to reduce the electricity bill.

Power factor correction

Power factor is the ratio of actual power (active power) being used in a circuit, expressed in watts or kilowatts (kW), to the apparent power being drawn from the mains supply, expressed in volt-ampere or kilo volt-ampere (KVA).

All motors depend on magnetism in order to operate. Magnetism is a force and in the physical sense is not consumed. In alternating current motors magnetic forces are required periodically. As a permanent magnet cannot be used, magnetism is produced inductively, but the electrical current needed for this is not fully used. Having produced the magnetic force, the current flows back into the supply system, and is known as reactive current. Although this reactive current is not used, it imposes a load on the electrical supply. For example, the actual load imposed by a 1 000 kW motor is calculated as follows

$$1\,000\,kW \div 0{,}8\ (\text{power factor}) = 1\,250\,KVA$$

which is the consumption the owner of the motor will have to pay to the electricity supplier.

It is possible to reduce this considerably by means of power factor correction. This is done by connecting a suitable capacitor to the inductive load such as a motor. Installation of this equipment can lead to a power saving of up to 20 %.

Pump starters

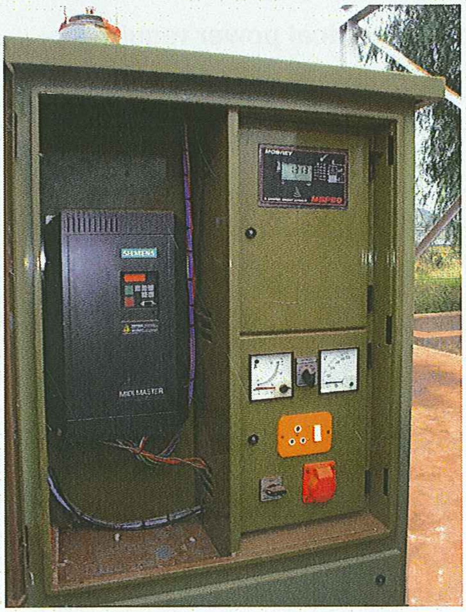
A pump starter is what gets the pump and motor going. This requires more than the normal operating energy until the pump is running at its required speed or revolutions per minute (rpm). This extra energy needed is called the starting current. The three most commonly used electric starters for pumps are the Direct on-line starter, the Star Delta Starter and the Soft Starter. As a rule of thumb, the starting current needed by each type of starter is as follows

- Direct on-line (the cheapest starting equipment) – roughly 6 x operating current
- Star Delta Starter (intermediate cost starting equipment) – roughly 3,5 x operating current
- Soft Starter (the most expensive equipment) – 2,5 x operating current.

Motors in the water industry generally (but not always) use the direct starting method, (Direct on-line or Star-Delta). This involves different methods of wiring the electric motor to the supply. However, the important issue is the start-up current. When wired directly, the start-up current of an electric motor increases from 5 to 10 times its normal running current. As electricity users pay for maximum demand, they will pay a high rate every time a motor starts up.

To minimize this, a motor can be connected in a star-delta configuration which is a two-stage starting process. Initially the motor starts in star-mode, where start-up current is reduced by a factor of approximately 1,73, and when the motor has reached its operating speed, it switches to delta-mode, where full motor torque is available. Star-delta is used only on larger motors (greater than 5,5 kW) and only if they do not need to start on full load conditions. The switchover from star to delta is controlled with a variable time switch which should be adjusted according to the load conditions of the motor.

The biggest factor when selecting a starter type is the available energy or current in the electricity network. For this reason most small installations start with Direct on-line starters. Once an installation becomes too big it can draw down the voltage of the electricity supply during start-up, and for this reason Star Delta and Soft Starters are installed. Medium sized pump installations use the Star Delta Starter while larger, more expensive installations use a Soft Starter.



A motor control centre with an integrated soft starter (cover of the panel removed for the photo).

Soft starters protect the installation

In most pumping installations there is mechanical equipment such as non-return valves, which prevent the fluid in the rising pipeline from flowing back through the pump when it is not operating. When a pump starts up by conventional starting methods, it immediately has a full load, and this causes the non-return valve to open very rapidly. The same happens when the pump is switched off and the valve closes almost instantaneously. This fast opening and closing is often accompanied by a loud bang as the valve slams open or closed, and it reduces the lifespan of the valve considerably. In addition to this, water hammer also occurs when sudden changes of velocity take place, as happens when a pump starts or stops.

The only way to prevent the risk of water hammer damage is to start and stop pumps gradually, and this is done by using a soft starter. Soft starters use electronic control circuits to build up the starting voltage gradually. Initially the voltage builds up fairly quickly to overcome friction, causing the motor to start turning, after which the voltage increases linearly until the full voltage is reached. When power is shut off, the soft starter has a ramp-down feature which gradually reduces the voltage across the motor terminals until the motor stops.

These starters can be programmed onsite to generate ramp-up and ramp-down intervals that best suit the load, which may be a pump, conveyor belt, etc. Soft starters are extremely reliable, operate silently and have no mechanical contactors or holding coils to worry about. Soft starters were initially quite costly but have become more affordable over time. They are the ideal solution for most pumping applications. Their one limitation is that they can only be maintained by highly skilled personnel. If a soft starter fails, the complete unit must be replaced, as the electronics that control the voltage cannot be repaired onsite.

Soft starters also offer the best protection to the pumping installation as most have various built-in safety features to protect the motor against electrical surges, phase-drops and under and over current anomalies.

learn more about

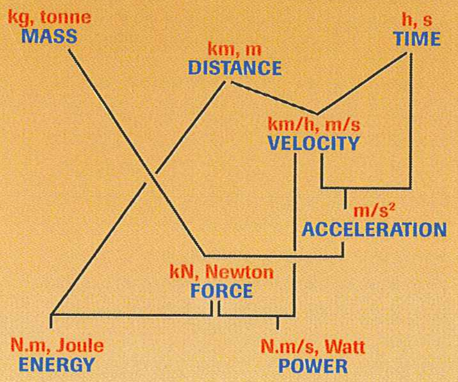
1 440 meters per second!

Water hammer (or, more generally, fluid hammer) is a pressure surge or wave caused by the kinetic energy of a fluid in motion when it is caused to stop or change direction suddenly. Kinetic energy is the force of the movement of the liquid mass in a pipe, and is proportional to the mass of liquid times the square of the velocity. Water hammer is due to sudden increase in the pressure of a liquid, due to an instantaneous conversion of momentum to pressure. This is caused by a very rapidly moving pressure wave in a closed conduit, usually resulting from a sudden stoppage or change in the mass velocity. Typically, in a hard walled pipe the pressure wave of water hammer travels to reflection point and back at a velocity in the order of 1 440 metres per second.

learn more about

Units of measurement in Newtonian Physics

Surprisingly, all calculations for civil engineering are done by applying our well-known number system (algebra) to units of measurement derived from only three basic physical entities: mass, length and time.



Newton measurements diagram

The units of measurement for these three entities in the metric (SI) system are as follows

- **mass** is measured in kilograms (kg) or tons. The mass of a litre of water is exactly 1 kg.
- **length (distance)** is measured in metres (m) or kilometres (km).
- **time** is measured in seconds (s) or hours (h). The pulse rate of an adult at rest is about one beat per second (60 beats per minute).

The derived units of measurement are the following

- *speed* or *velocity* is obtained when length is combined with time, and the resultant unit of measurement is metres per second (**m/s**) or km per hour (**km/h**)
- *acceleration* is obtained when speed is again combined with time, giving the unit of measurement of metres per second per second (increase or decrease in speed per second) (**m/s^2**).

Now the plot thickens, and this is where, a little more than 300 years ago, the genius of Isaac Newton came in

- **force** is the product of mass and acceleration (**$kg.m/s^2$**) which is called **Newton (N)**

Continued on the next page

learn more about

Another brainwave of Sir Isaac Newton was that the gravitational effect of the earth can be expressed as an acceleration, i.e. in m/s². It has been established by measurement that the gravitational effect on the surface of our planet is 9,81 m/s². In simple terms it means that if an object is dropped, it will, after one second, travel at a speed of 9,8 m/s (about 35 km/h). One could easily test this by dropping a dense object from a height of 4,9 m , which should then reach the bottom in exactly one second. (The average speed of travel starting from zero is half the final speed of 9,81 m/s).

More playing around with the three basic entities yields the following

- *energy* is the product of force times distance (length): m·kg·m/s² or **kg·m²/s²**, which is called **Joule (J)**

And finally,

- **power** is the product of force times speed: kg·m/s²·m/s or **kg·m²/s²** or **Watt (W)**

This is the well-known unit **kW** in which, for example, the performance of a car or a lawnmower is measured. Power can also be defined as energy per time unit viz. Joule/second.

Lifting water

These units of measurement apply to any physical object with mass, even water. To raise 1 kg of water (1 litre) one metre in the gravitational field of the earth requires 9,81 Joules of energy. To do this in one second 9,8 Watts of power is required. Then, to raise 10 litres of water per second as high as 100 m, 9,81 kW of power must be available, to which must eventually be added friction losses in the pipeline and the efficiency factors of the drive motor and pump.

Text and diagram: Christian Schumann

Illustration Internet

Sir Isaac Newton (1643–1727) was an English physicist, mathematician, astronomer, natural philosopher, alchemist and theologian.

His treatise *Philosophiæ Naturalis Principia Mathematica,* published in 1687, said to be the greatest single work in the history of science, described universal gravitation and the three laws of motion, laying the groundwork for classical mechanics. He is also famous for calculating the gravity constant for the earth as 9,81 m/s², which is associated with the story of the apple falling on his head.

Engines and Engine Maintenance

The majority of municipal water supply schemes are powered by electricity from the Eskom distribution network. This is also the preferred option to drive pumps. Where there is no electrical supply, petrol and diesel engines can be used to generate the required energy. Diesel engines are preferred due to better fuel efficiency. There are very few engine-driven supply systems in the Northern Cape. This chapter gives a brief overview of how a diesel engine works and how to maintain it.

A diesel powered pump set – a fire water-booster pump station at the Vioolsdrif Border Post.

How a diesel engine works

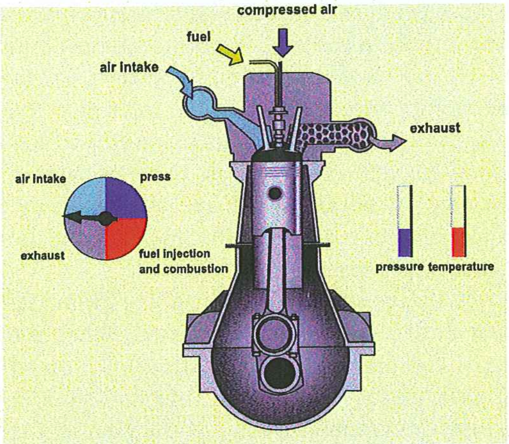
A diesel engine, like a petrol engine, uses the energy released by the combustion of fossil fuels to drive a piston up and down. The piston is connected to a crankshaft which converts linear motion (up and down movement) into the rotary motion required to power a pump, alternator or other application for which the engine is needed. Both petrol and diesel engines convert energy from the combustion process to motion which moves the piston. The difference between the two is how the combustion occurs.

A diesel engine works on the principle that air heats up when compressed. When the air is compressed in the cylinder of a diesel engine, diesel fuel injected into the cylinder ignites spontaneously due to the heat of the compressed air. This is possible as a diesel engine has a very high compression ratio, compressing the air up to one twentieth of its original volume.

A petrol engine also compresses the air, but to a lesser degree – usually to only about one tenth of its original volume. When the petrol is injected, it is ignited by a spark produced by a spark plug, fitted into the top of the cylinder. This requires that the spark and the injection of fuel occur just prior to highest compression of the air.

Most engines use a four stroke principle. The four strokes are

- **Air intake or Intake stroke.**
  Inlet valve opens and a vacuum caused by the downward moving piston sucks in air through the valve.
- **Pressurisation or Compression stroke.**
  At the bottom of the inlet stroke, the inlet valve closes and the piston moves upward in the cylinder compressing the air.
- **Fuel injection and combustion or Combustion stroke.**
  When the piston reaches the top of the compression stroke, the fuel is injected and ignites. The burning fuel causes an expansion of the gasses which forces the piston downward again.
- **Expulsion of the burnt out gases or Exhaust stroke.**
  When the piston has moved to its lowest position due to the expansion of the burning gasses, the exhaust valve opens and the momentum of the engine flywheel pushes the piston upward expelling the burnt gas mixture from the cylinder.



Cross-section through a diesel engine
Illustration Internet

This four step cycle is repeated several thousands of times every minute to create continuous rotation of the crankshaft. The injection of fuel into the cylinder is the most complex aspect of the process. The idea is to inject a fine mist of fuel that is evenly circulated within the cylinder to ensure that optimum combustion takes place, in order to force the piston down at maximum efficiency to minimise fuel consumption and maximise the power generated. Most diesel engines are fitted with glow plugs in the cylinder to preheat the air in the cylinder during a cold start. This is to ensure that the compressed air generates sufficient heat to ignite the diesel fuel at startup. Glow plugs are usually connected to a timer circuit which turns them off after a few seconds so they do not operate once the engine is running.

A diesel or petrol engine is a mechanical device with rotating shafts supported by bearings. All these moving parts are lubricated by oil to decrease friction. In addition, all moving parts as well as the stationary parts are subject to heat due to the combustion process. Excess heat that builds up and decreases the lubricating properties of oil must therefore be dissipated by either an air or water cooling system.

An internal combustion engine is thus a collection of systems which operate together as a unit to produce motive power. If any one of these systems fails or malfunctions, the engine fails to produce power. Accordingly, regular maintenance is required to keep an engine in perfect operating condition.

Diesel engine maintenance

Maintenance requirements differ depending on the application. An engine which runs continuously for long periods requires less frequent maintenance than an engine which runs intermittently for short periods. Diesel engines have four primary requirements to ensure a long life and efficient operation

- **Clean air filters –**
  a dirty air filter prevents sufficient air from entering the cylinders and makes the combustion process inefficient.
- **Clean fuel filters –**
  a dirty fuel filter leads to fuel starvation which decreases the efficiency of the engine
- **Clean oil filters –**
  due to the build-up of heat and corrosive products released during combustion and by physical wear, it is essential that the lubricating oil be continuously filtered to remove these elements to maintain the lubricating properties of the oil.
- **Regular oil changes –**
  due to the build-up of heat, corrosive products released during combustion and so forth, the lubricating properties of the oil decline over time (even with filtering),

leading to increased wear and heat build-up, unless it is changed.

Although requirements for different manufacturers may differ, as a general guide, the following procedures and time frames are applicable for most diesel engines.

Procedure \ Interval	8 hours	250 hours	500 hours	1 000 hours	2 500 hours
Check fuel tank level	✓				
Check coolant level	✓	✓	✓	✓	✓
Check drive belts		✓	✓	✓	✓
Clean fuel pump strainer			✓	✓	✓
Empty water trap	✓	✓	✓	✓	✓
Replace fuel filter element			✓	✓	✓
Check injector tips for atomization					✓
Check and adjust idle speed					✓
Check lubricating oil level		✓	✓		
Check lubrication oil pressure gauge	✓	✓	✓	✓	✓
Replace lubricating oil		✓	✓	✓	✓
Replace lubricating oil filter		✓	✓	✓	✓
Clean engine breather vent valve					✓
Clean air filter element		✓	✓	✓	✓
Replace air filter element				✓	✓
Clean turbocharger lubricating drain pipes					✓
Check condition of the exhaust and silencer				✓	✓
Check and adjust the valve tip clearances					✓
Check alternator, starter motor, etc					✓
Clean starter battery terminals		✓	✓	✓	✓
Check battery electrolyte levels and top up		✓	✓	✓	✓

Typical problems and how to deal with them

Properly operated and maintained, diesel engines are reliable. Make sure to follow the O&M guidelines provided by the manufacturer. Here are a few typical problems and how to deal with them.

Excessive black smoke from the exhaust

Black smoke is normal on start-up, but when continuously emitted, the following could be possible causes

- Poor fuel injection – check injector spray patterns
- Air inlet restricted – dirty air filter
- Poor engine timing – have a specialist check the timing
- Internal engine problems, such as the sump compression, etc.

Excessive white smoke from the exhaust

White smoke on start-up is normal, but continuous white smoke may be caused by

- Some or all glow plugs malfunctioning - replace
- Plugged or restricted fuel return line
- Bad fuel injection – check injector spray pattern
- Poor engine timing – have a specialist check the timing
- Low compression – have the piston rings checked for wear.

Engine will not start

- Low cranking speed – check battery condition
- Some or all glow plugs bad – replace
- No fuel to cylinders – check
- Fuel filter blocked – replace
- No voltage to fuel cut-off solenoid – check and repair
- Dirty fuel
- Bad fuel injection – check injectors
- Poor engine timing
- Low compression
- Other internal engine problems.

Engine runs but has low or almost no power

- Blocked or restricted fuel return line
- Poor or contaminated fuel
- Poor engine timing
- Air inlet restricted – replace air filter
- Other internal engine problems.

Engine runs rough

- Some or all glow plugs bad – replace plugs
- Plugged or restricted fuel return lines
- Insufficient fuel supply
- Poor fuel quality
- Bad injectors – check injector spray patterns
- Idle speed too low- adjust
- Air in fuel – check fuel lines for leakage
- Fuel leakage between injector pump and injectors.

General maintenance

Besides the above basics, it is important to have good housekeeping procedures in an installation, or it will soon become very messy. It is necessary to keep the engine room clean and free from oil spills, etc. A good wipe-down once a week of the control panels, the engine and all equipment serves to keep the installation neat and clean.

Make sure the engine room is well ventilated and that the exhaust emissions are discharged outside the engine room.

Remember, when diesel engines are not in use, they should be run for at least 1 hour each month to lubricate all internal parts and ensure that batteries are fully charged. Check all switchgear on engines and generators regularly for correct operation.

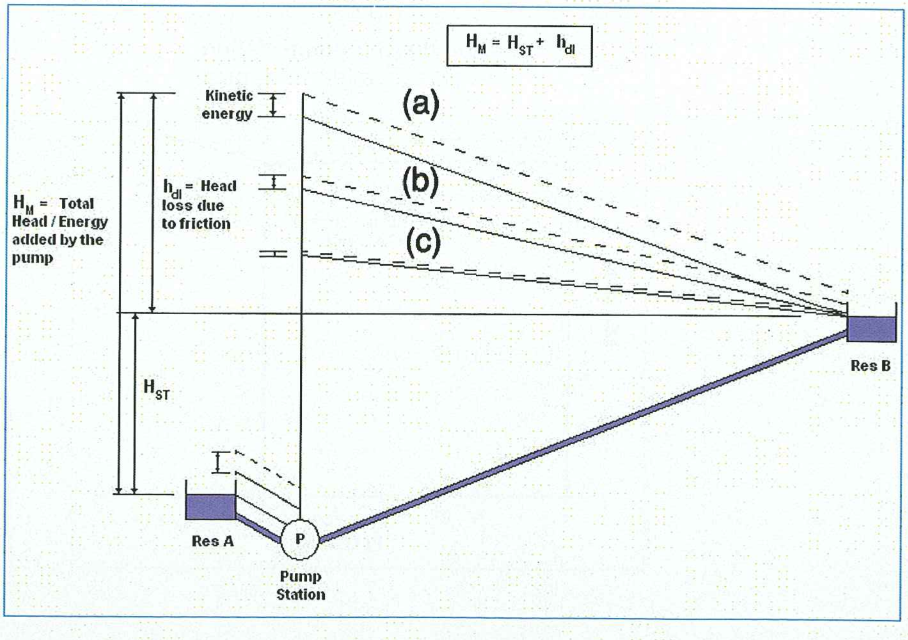
Pumps and Associated Equipment

To understand the basics of pumps we must first understand two elements – the hydraulic grade line and the duty point.

The hydraulic grade line

Municipalities often use pumps to pump water from a low-lying reservoir or source to a high-lying reservoir. The difference in height between the two water levels is called the static head or HST. The energy required or hydraulic grade line is shown by lines (a), (b) and (c) in the illustration. It shows that the pump energy enables the water to overcome the static head (HST), as well as friction (hf) in the pipeline. Any additional energy over and above (HST) is available to overcome friction. Any additional energy, over and above that required to overcome friction, increases the speed or velocity at which the water flows to the higher reservoir. The higher velocity consumes the extra energy.

In the figure, (a) represents the situation where the most energy is made available, (b) shows less energy transferred by the pump and (c) shows the least. The dashed line depicts the actual hydraulic grade line, as the energy of the water is the sum of its potential head or pressure and the kinetic or movement energy. Note that (a) has more kinetic or movement energy, as the dashed line is further above the solid line than in the case of (b) and (c).



Hydraulic grade line diagram

If more energy is added, more energy is available to overcome friction and the flow rate is increased.

Remember that only specialised variable speed pumps allow for flow rate adjustments ,as described above. Most pump installations are designed and built for a fixed flow rate that cannot be changed or adjusted.

Duty point

The engineer responsible for the design of a pump station chooses a pump with a specific duty point, i.e. the head and flow at which the pump operates most efficiently. In other words, the maximum water is moved to the desired location for each kilowatt hour for which the municipality pays. In short, this is when you get the best value for money.

The duty point is based on the intersection of two curves – the pump curve and the system curve. The pump curve depends on the characteristics of the pump and is given by the pump manufacturer. The system curve is determined by the characteristics of the rising main or pipeline. Factors that influence this curve are the height that needs to be overcome, and the pipeline diameter, roughness and configuration, (bends and sharp changes in direction). Valves and any narrowing in the pipeline also influence this curve. If any of these characteristics are significantly changed, the duty point will move and influence the efficiency of the pump.

learn more about

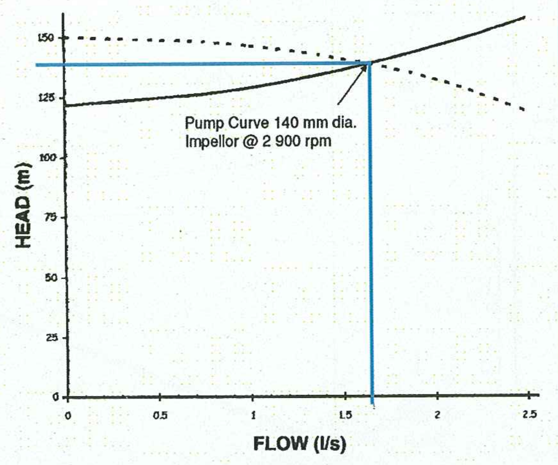
How to use a pump curve – *See page 25.*

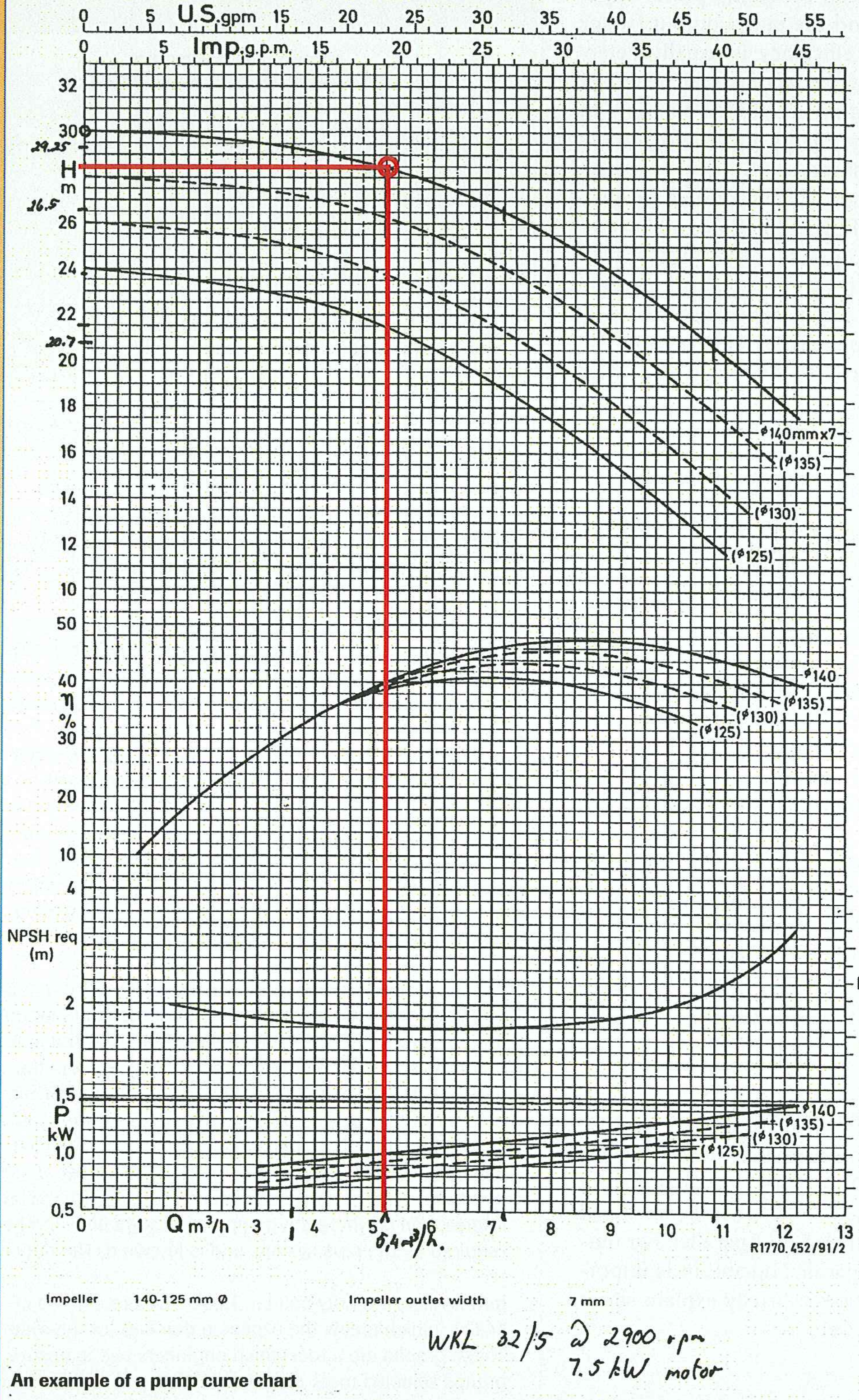
Firstly one obtains the correct pump performance curve from the manufacturer. Then one plots the flow required on the flow scale of the curve, usually with the horizontal scale at the bottom of the page. A vertical line is then drawn from the flow scale to the point where it intersects the pump curve. More often than not there will be a series of four or five curves on a single page. The different curves represent the performance of the pump using impellors of different diameter. A single pump casing can usually be used with a series of impellors of varying diameters to obtain a specific performance.

The required total delivery head is plotted on the vertical scale of the curve and a horizontal line is drawn across the page to the point where it intersects the vertical line drawn from the flow scale. This point of intersection is known as the duty point of the pump. If the duty point does not fall exactly on the pump curve, it is good practice to always select the impellor size just above the duty point. Now one has the pump model and the impellor size to deliver the required flow at a specific head. The next step is to select the correct motor size.

Generally there are different power requirements for each size of impellor, so normally if there are curves for four impellors there will also be four power curves just below these. Where the vertical line from the flow scale crosses the power curve corresponding to the impellor size selected, one can read off the power required of the pump motor in kilowatts. The above process is illustrated graphically on the performance curve *on page 25.*

Nakop booster pump station
– system curve for rising main





An example of a pump curve chart

Pump efficiency

Efficiency is defined as the ratio of work done by the pump and the work done on the pump or the ratio between the pump power input (electrical kW) and the pump output (water kW). The pump efficiency is usually determined by the pump manufacturer on a test bed, where the pump is tested at a variety of duty points and the energy inputs and outputs are carefully measured.

Every pump has what is termed the Best Efficiency Point (BEP) – the flow and head at which the pump operates at its highest efficiency. These figures are usually also presented graphically on pump performance curves. This enables an engineer to select a pump for a required duty so that it operates at its best efficiency point or as close as possible to this point.

Pump efficiency is calculated as follows

$$\text{Efficiency} = \frac{\text{Energy produced}}{\text{Energy input}}$$

or: $$\frac{g \times \rho \times Q \times H}{P}$$

where g = 9,81 m/s (gravitational constant)
ρ = density of water (1000 kg/m^3)
Q = flow in m^3/s
H = head in m
P = power input on pump shaft in kW

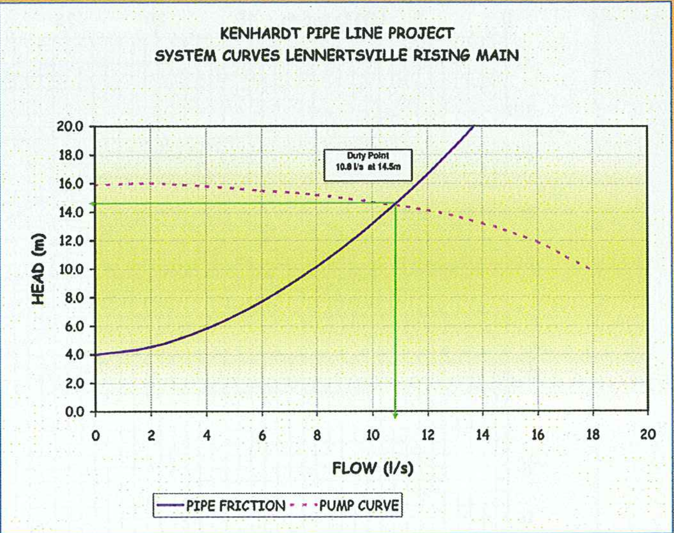
Efficiency is unit-less (e.g. 1,0, 0,9, 0,8, etc.), or expressed as a percentage (e.g. 100 %, 90 %, 80 %, etc.). In reality it is impossible to have an efficiency of 1, which would mean that the energy output is the same as the input. Different factors such as friction would reduce the output.

Pump configurations

Pumps can operate simultaneously, but depending on the pump configuration, different results are obtained. Pumps can be arranged to operate either in series or parallel. For municipal use, only parallel operation is important. We will, however, briefly explain series configurations as well.

learn more about

Pump curves and system curves



A typical system curve showing the pipe friction curve with the pump curve superimposed. The pump duty point is where the two curves intersect.

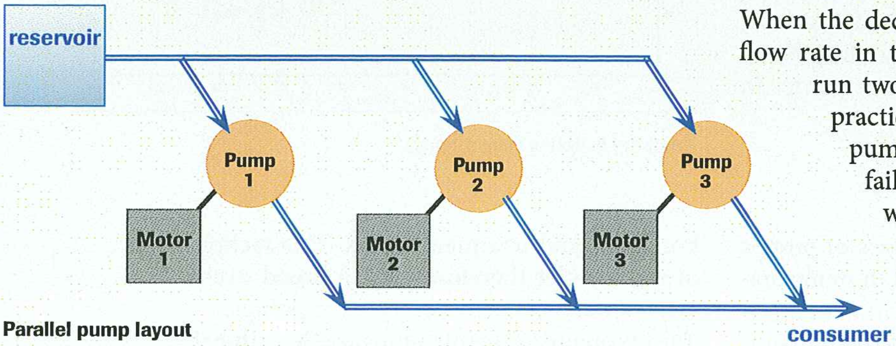
The graph above shows a typical pump curve (dotted curve) superimposed on a system curve (solid blue curve). The system curve is an indication of how the friction increases as the flow through the pipe increases, due to increased water velocity. The difference in elevation between the pump centreline and the top of the reservoir where the water is delivered is only 4 m, hence the system curve starts at a head of 4 m with zero flow through the pipe. This is known as the static head. As the flow (on the horizontal scale of the graph) increases, the friction in the pipe increases, which requires a higher pumping head. The blue curve therefore represents the pressure required to pump water through the pipe between a range of zero to 20 litres per second.

In order to find the duty point for this system, a pump is selected from the manufacturer's brochures to meet the required duty of 10 ℓ/s. The head generated by the pump at flows ranging from 0 to 20 ℓ/s is now read off from the pump performance curve supplied by the manufacturer. These values are now plotted on the same graph as the system curve of the pipe and fitted with a curve, the solid blue line. The two curves will now intersect each other at some point, if the pump has been chosen correctly. This point of intersection is where the pump delivers the flow and head required by the pipe system, and is known as the duty point.

In this case, the duty point is 10,8 ℓ/s at a total head of 14,5 m, which meets the expected demand for the system. These graphs are a tool which engineers use to ensure that pumps selected meet the required demand of the water supply system.

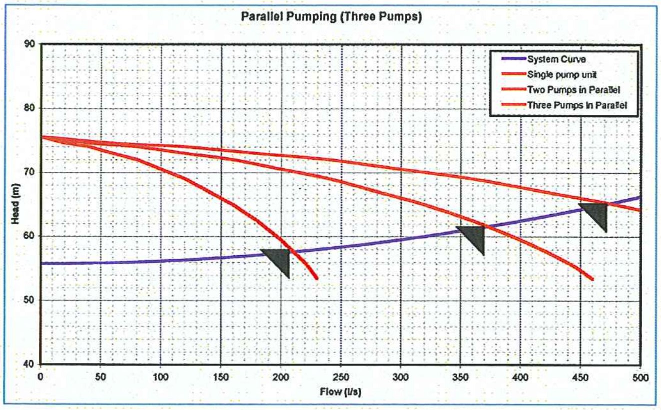
Pumps in parallel

If the flow rate of one pump is no longer sufficient to satisfy the demand for water, as often happens when a town grows, then installing two pumps in parallel is often the easiest solution. The combined head quantity curve is found by adding the individual flow rates at the same head.

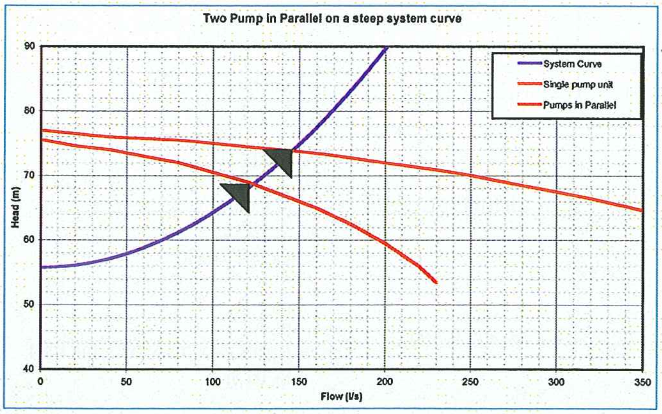


Parallel pump layout

Centrifugal pumps can be operated in parallel without problems when the head at no-flow and the steepness of all pumps are equal (in other words, all the pumps in the pump station are the same).



Three pumps in parallel



Two pumps in parallel

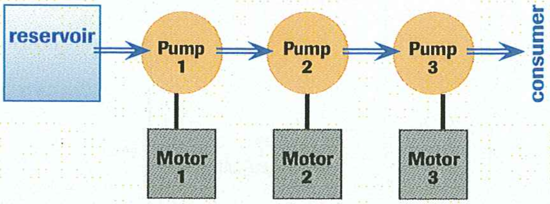
The illustrations show how the flow rate can be increased by running two or three pumps in parallel. However, when pumps with very flat characteristic curves operate in parallel, or if the system curve is very steep, the total flow rate may not be much greater, so that parallel operation becomes uneconomical.

When the decision is taken to increase the flow rate in this manner and permanently run two pumps in parallel, it is good practice to install a third backup pump in case one of the two pumps fails. Common practice is to always have one pump more than needed to do the job.

Most pump stations serving areas with large growth potential must also make provision for future pump unit installations. The municipal technical manager must consult with the town planner to determine what pump stations might be affected.

Pumps in series

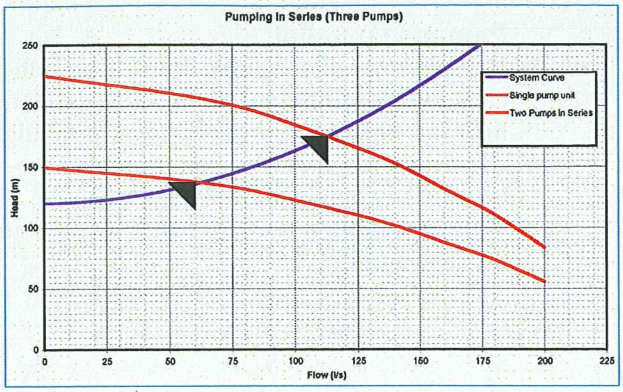
Pumps are used in series if a specific high pumping head cannot be achieved with one pump. It is then possible to double the head by installing a second pump in series in the same pipeline. If two or more pressure stages are built into one pump, it is called a multi-stage pump. In most cases where a high head is needed, a multi-stage pump is used rather than pumps in a series. For this reason municipal maintenance teams will rarely encounter pumps in series configurations.



Series pump layout

There are exceptions to the rule when the installation of a multi-stage pump is not feasible and two or more pumps are installed in series, e.g. when a system has very long pipelines and pumps with very high flow capacity are used.

The figure alongside shows pumps in a series configuration and the Head over discharge graph. In this particular case one pump would not have been able to deliver the static head required. Two pumps in series do the job at a low flow rate of about 60 ℓ/s. Three pumps in series deliver 112 ℓ/s.



Pumping in series (two pumps)

Types of pumps

This booklet focuses on the types of pumps and associated equipment used in pump stations, such as a booster pump station between boreholes and reservoirs or treatment plants, or a pump station between a ground reservoir and an elevated reservoir. However, pumps and associated equipment are also used at boreholes and treatment plants. This section of the booklet therefore gives a broad overview of the most common types of pumps. The two main groups of pumps are Centrifugal Pumps and Positive Displacement Pumps. The diagram shows the classification of pumps.

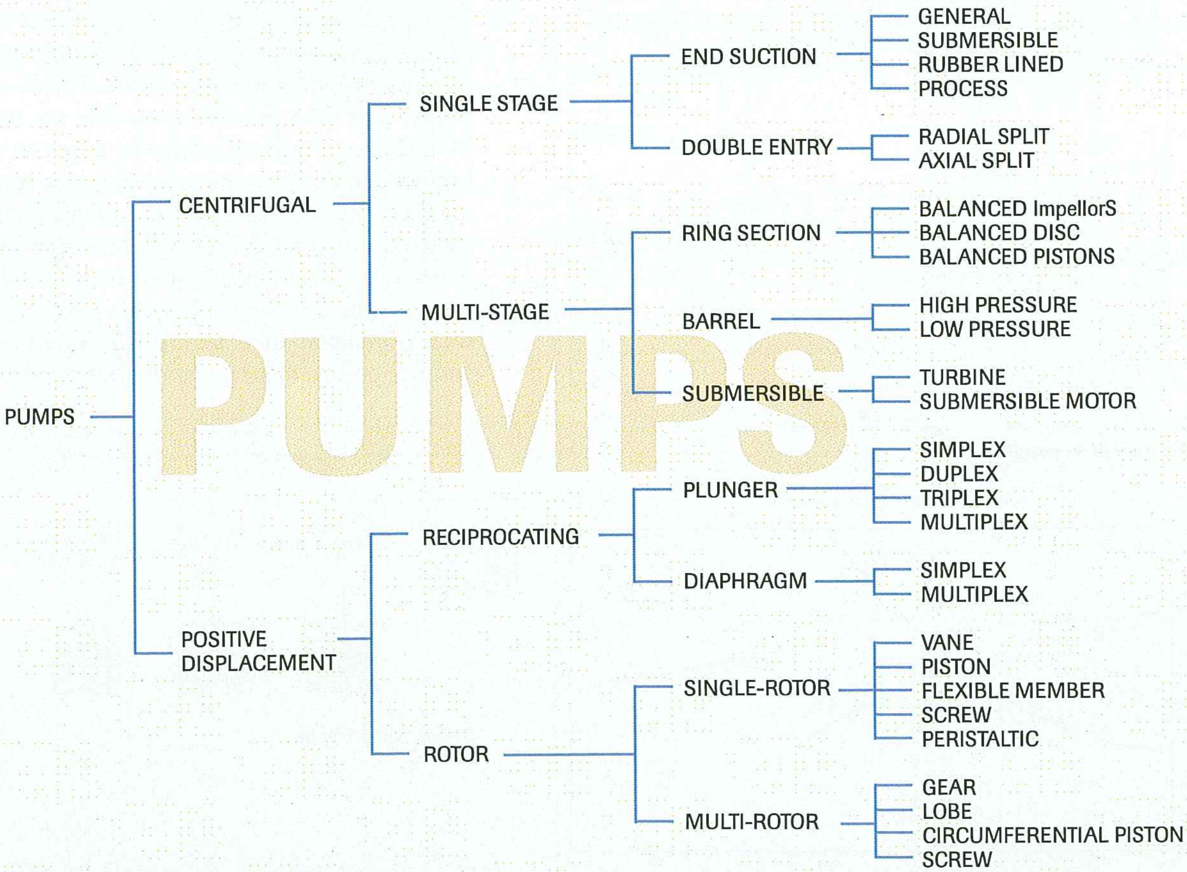
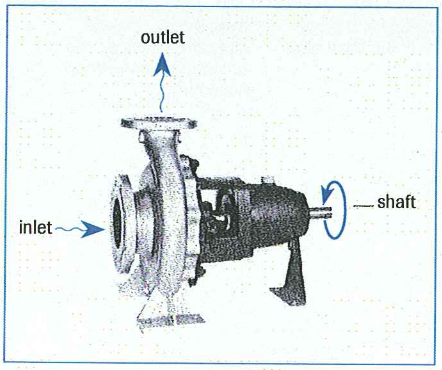
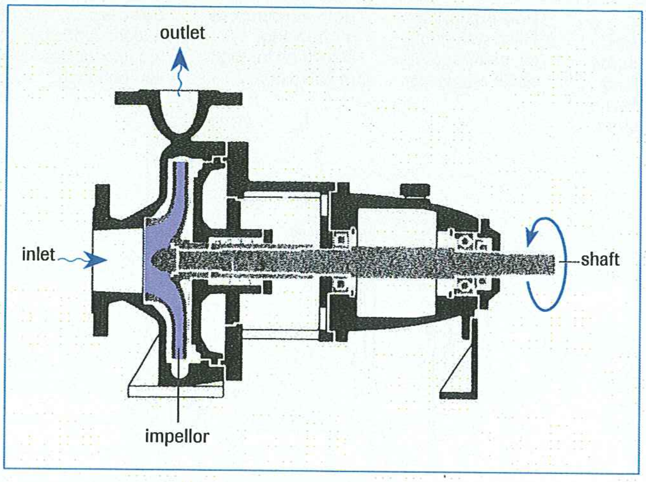


Table from South African Pump Manufacturers Association

Centrifugal pumps

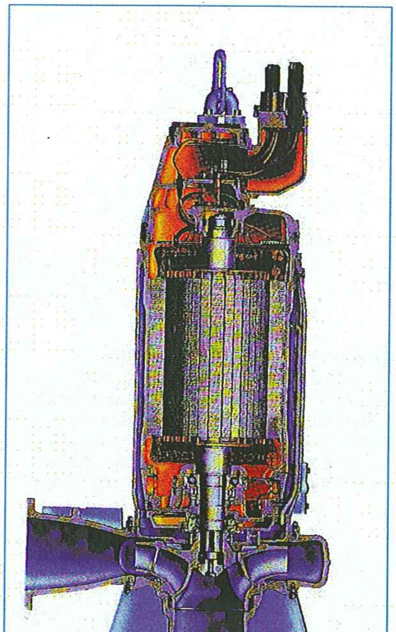
Centrifugal pumps move water by exerting centrifugal forces on it, i.e. the same force that keeps water inside a bucket when you swing it over your head. The water is forced into a rotating impellor which discharges it at a higher pressure and velocity at the periphery.





End suction pump – volute casing
right **cross-section**
Illustration from Pumps Principles & Practice

Illustration Internet



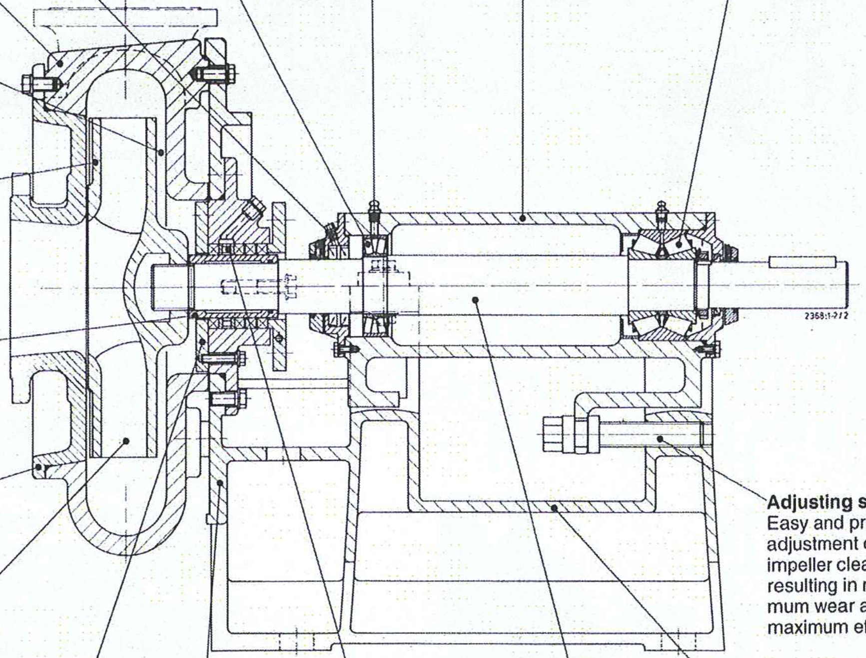
Cross section of a single-stage submersible pump
Illustration Flygt website

There are many types of impellors available depending on the application of the pump. If the required pressure cannot be delivered by one impellor, another pump can be added in series, or a multi-stage pump with more than one impellor can be used.

The selection of a pump for a specific application should be done with care. There are several factors that need to be taken into consideration, of which the following are the most important

- the flow rate of the water that needs to be pumped, i.e. how much water is to be pumped over a set time period. This can be expressed in litres per second or cubic metres per hour or megalitres per day (day = 24 hours).
- the static head – the physical difference in level that the pump must lift the water
- the delivery piping friction losses – due to friction between the water being pumped and the material of the pipes connected to the pump outlet. This includes friction caused by valves, bends, reducers and other fittings installed in the pipeline.
- the inlet piping friction loss – due to friction between the water being pumped and the material of the pipes connected to the pump inlet.

Design Features



Cross section of a centrifugal end suction pump
Illustration from KSB

- the section head – the vertical distance between the water surface level and the centre of the pumps impellor
- the net positive suction head – centrifugal pumps operate by the spinning impellor, creating an area of low pressure at the centre of the impellor due to centrifugal forces. Atmospheric pressure is then greater than the pressure at the centre of the impellor, and exerts a force on the surface of the water, pushing it into the centre of the impellor via the inlet piping. Theoretically, it is thus not possible to have a suction head in excess of 10 m, as the atmospheric pressure is approximately 10 m of water pressure. In practice this is limited to about 9 m, as the inlet piping friction loss also needs to be overcome by atmospheric pressure.

When all the above values have been determined by means of calculations and/or friction tables, a total delivery head is calculated by adding together all the delivery friction losses and the static head. With this information, one can now make a pump selection from a pump curve. *See page 24* for details on pump curves.

Centrifugal pumps can be subdivided into single-stage and multi-stage pumps. Single-stage pumps are usually used to pump larger volumes of water. Multi-stage pumps are used to lift water to a considerably higher level, and are typically used in mountainous areas or at steep river banks.

A centrifugal six-stage axial flow pump at Henkries pump station on the Orange River.

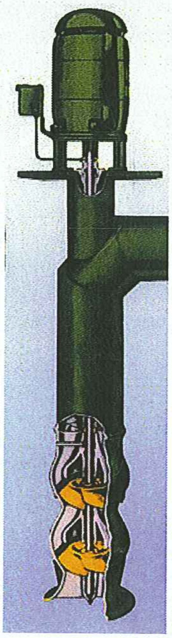
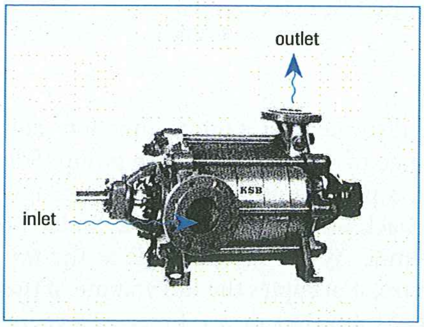
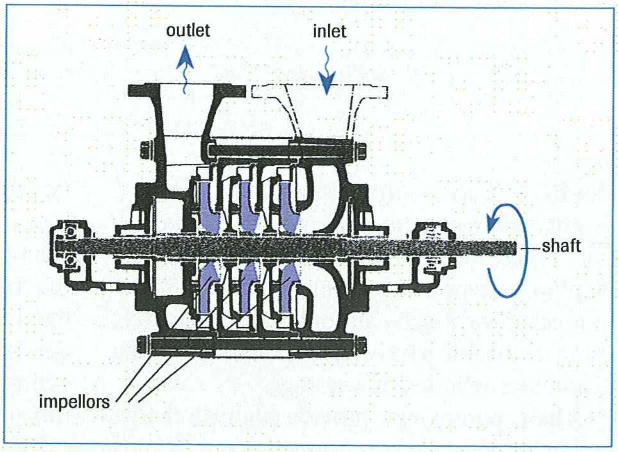


Illustration Internet

A centrifugal multi-stage axial flow pump with motor





Multi-stage pump with three stages, *above.*
Cross section or multi-stage casing set, *right.*
Illustrations from Pumps Principles & Practice

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Priming of pumps

In order for a centrifugal pump to function, its casing and impellor must be filled with liquid. A centrifugal pump cannot suck water. What happens is that the air pressure of the atmosphere forces the water into the center of the pump impellor, which is located above the level of the water surface. This means that at sea level, the theoretical height of a pump inlet above the surface of the water cannot exceed 10 m. However, in practice, it is considerably less than 10m due to inlet friction, height above sea level (atmospheric pressure decreases as the altitude increases), temperature and vapor pressure, which are all variable factors that need to be overcome before a centrifugal pump can function.

The earth's atmosphere extends approximately 80 km above the earth, and rests on the earth with a weight equivalent to a layer of fresh water 10 meters deep at sea level. To remove air from the pump cavities and the suction piping, the pump must develop enough head to equal the equivalent of this 1 bar pressure.

Unlike a positive displacement pump that can pump a liquid to any head as long as the pump body is strong enough, and there is enough horsepower available, the centrifugal pump can only pump a liquid to its rated head. This head is determined and limited by the diameter of the impellor and the impellor speed (rpm).

Since the weight of water is approximately 8000 times that of air (80 km vs. 10 m), a centrifugal pump can produce only 1/8000 of its rated liquid pressure.

In other words, for one metre of water that has to be raised to prime the pump, the centrifugal pump must produce a discharge head of approximately 8000 m, and that is impossible with conventional impellor diameters and speeds.

All of this means that if you intend to use a centrifugal pump to lift water from a source below the centre line of the pump impellor, you are going to have to come up with some sensible method of priming or filling it. Options include:

- Installing a foot valve in the suction piping to ensure that the liquid will not drain from the pump casing and suction piping when the pump stops. But keep in mind that these valves have a nasty habit of leaking.
- Evacuating the air in the system with a positive displacement priming pump operating between the pump and a closed discharge valve.
- Filling the pump with liquid prior to starting it by removing the delivery piping and pouring water into it with a bucket. This is often the method used on small portable pumps.
- Converting the application to a self-priming pump that maintains a reservoir of liquid at its suction end. Self-priming pumps create a vacuum that removes all the air from the suction piping.

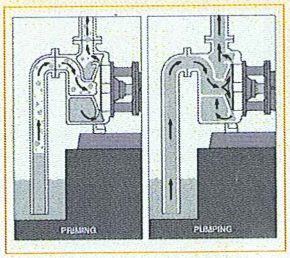


Illustration Internet

Cross section showing the functioning of a self-priming pump.

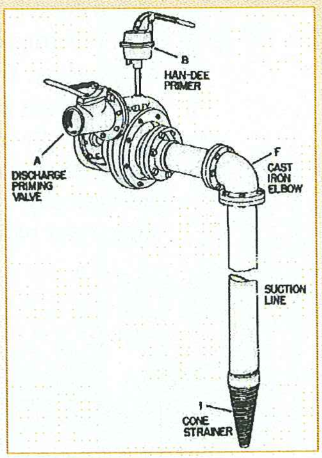


Illustration Internet

Example of a hand operated vacuum pump (B) used to prime the main pump.

Positive displacement pumps

Positive displacement pumps come in two distinct types, rotary and reciprocating piston or diaphragm types. These pumps transfer fluids by mechanical means without centrifugal force, using a movable part in an enclosed cavity, like piston in a cylinder, or a syringe.

These pumps can provide high discharge pressures and can also pump viscous liquids like oil. However, they are more expensive than centrifugal pumps and more costly to maintain.

Positive displacement pumps function due to a change of volume inside the pump. For example, a piston pump consists of a piston moving back and forth inside a cylinder of fixed volume. When the piston is at the top dead centre, it occupies the full volume of the cylinder. As it moves down it creates a vacuum and a fixed volume of liquid flows into the cylinder due to atmospheric pressure. On the upstroke it pushes the liquid out of the cylinder into the delivery pipe. It thus 'positively displaces' the liquid being pumped. These pumps cannot pump against a closed valve. Either the piston will break or the pipe will burst.

Different types of positive displacement pumps are used by municipalities, The most common being reciprocating pumps, rotary pumps, gear pumps, peristaltic pumps and progressive cavity pumps.

Reciprocating pumps

These pumps have a piston or a moving diaphragm. They pump a constant volume at a given motor speed and deliver the same flow at any pressure. These pumps are extremely efficient and limited in pressure only by the physical strength of the pump.

Typical examples are the dosing pumps used for chemical dosing. They are equipped with a motor driving a crankshaft which changes rotational movement to reciprocating movement. A piston attached to the crankshaft moves back and forth horizontally or vertically as the crankshaft rotates. The piston is connected to a diaphragm made of flexible material such as rubber or neoprene, that creates a vessel of fixed volume into which the liquid is sucked, and then discharged.

learn more about

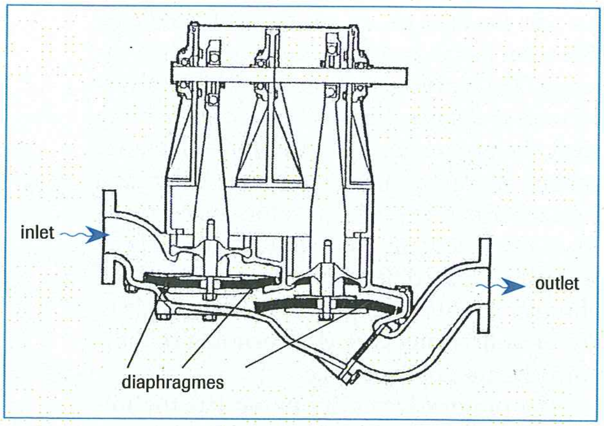
Dosing pumps and their maintenance

Positive displacement pumps are most commonly used in municipal water supply systems as dosing pumps. They enable accurate dosing of disinfectants and coagulants into the potable water supply. Maintenance on these units is important to prevent incorrect dosages being applied. Regularly check these pumps for any residue or deposit of granular chlorine that might hinder the pumping. Also check the diaphragms every month for signs of tearing.

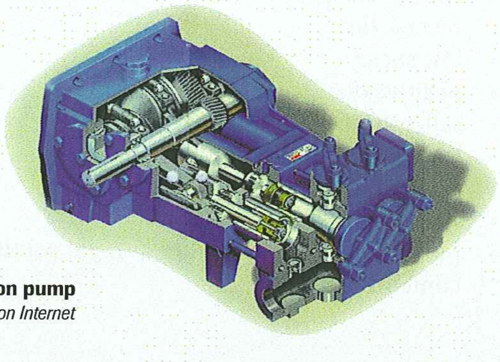
Many package treatment plants use HTH or granular chlorine for disinfection. The HTH is dissolved in water and then dosed with a dosing pump. As the chemical composition of HTH is Calcium Hypochlorite, the calcium tends to scale in the pump inlet and outlet piping, as well as on the diaphragm. This can be countered by pumping a 20% solution of hydrochloric acid through the whole system for at least 10 minutes. This should be done at least once every three months to prevent blockages due to calcium scaling, to ensure that the pump operates accurately.

Illustration Internet

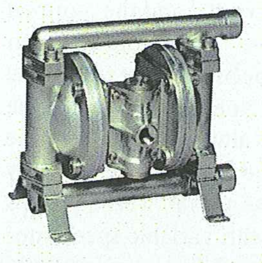
An Alldos diaphragm dosing pump



Diaphragm pump
Illustration from Pumps Principles & Practice



A piston pump
Illustration Internet

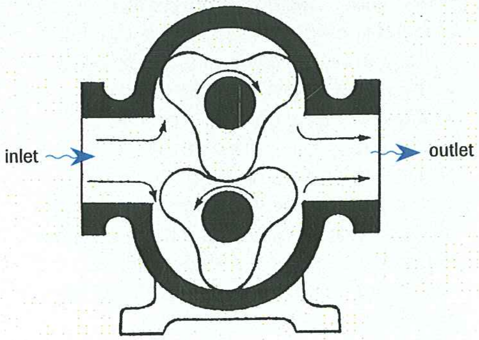


Example of a reciprocating diaphragm pump
Illustration Internet

Rotary pumps

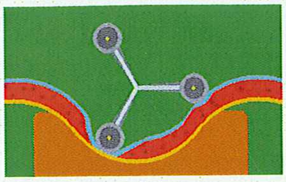
Rotary pumps include the gear pump, progressive cavity pump and the peristaltic pump. Rotary pumps are not equipped with pistons but function due to the rotation of the pumping element, which may have several different forms.

Gear pumps are mostly used where oil is pumped. They have two rotating gears that mesh, compressing the liquid between the gear teeth, and creating the force that moves the liquid. These are usually low volume/high pressure pumps. Common applications are hydraulic pumps on earth moving machinery, where the pump supplies oil pressure to operate the hydraulic jacks on the machine.

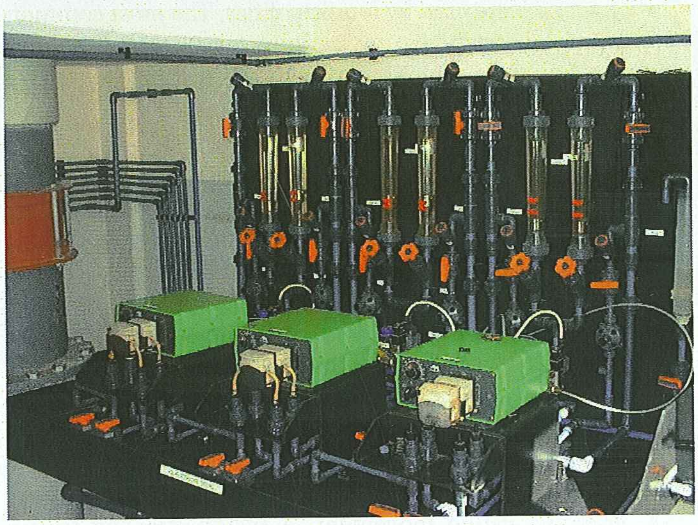


Lobe Rotor Pump
Illustraion from Pumps Principles & Practice

Peristaltic pumps are often used to transfer chemicals, as they have an extremely accurate delivery. They can also be used for pumping sludge. Peristaltic pumps are equipped with rollers rotating inside a special housing. A tube manufactured from flexible material is then pinched between the rollers and the housing of the pump. As the rollers rotate, the tube is pinched closed in front of the roller. As the tube regains its shape after being released from the roller, a vacuum is created and the pumped liquid enters the tube. The liquid is then pushed through the tube by the next roller. The great advantage of this type of pump is that the liquid being pumped is always enclosed by the tube and does not come into contact with any mechanical parts of the pump. These pumps can also be equipped with variable speed motors which allow them to deliver very accurate volumes, over a large range of flows.



Cross section showing the operating principle of a peristaltic pump.
Illustration Internet

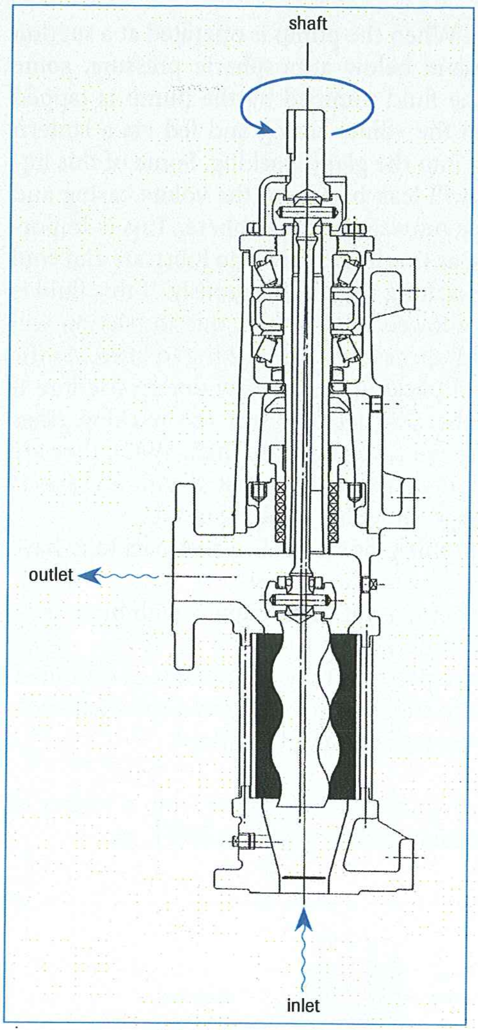


Peristaltic pumps used for dosing of chemicals.

Progressive cavity pumps have a rotor which turns inside a fixed stator, pumping the fluid axially between the meshing stator screw threads. A progressive cavity pump has a steel alloy rotor and a stator made of rubber. The stator always has one more lobe than the rotor and the pair can have 1:2, 2:3, 3:4 etc. configurations. The rotor has an eccentric movement when rotating. The eccentric rotor is joined by a universal joint or flexible shaft to a concentric rotating shaft. Stators are normally made out of natural rubber; however, materials such as teflon and even metal can be used. The rotors are normally made out of tool steel or stainless steel, and can sometimes have different coatings such as hard chrome. Pump housings are normally made of cast iron or stainless steel, depending on how corrosive the application is.

The progressive cavity pump has the following advantages

- reverse flow
- low shear
- positive displacement
- self-priming
- low noise
- continuous flow – no pulsating
- metering capability
- pumping of liquids with a high solids content.



Progressive cavity pump
Illustration based on drawing from Pumps Principles & Practice

Progressive cavity pumps can be mounted horizontally or vertically, depending on the application. Stator and rotor sizes can vary from a few inches to 20 feet in length. The length determines the stages on the pump. Applications of progressive cavity pumps vary. In the wastewater industry they are often used to pump sludge and slurry, animal waste, chemicals, etc.

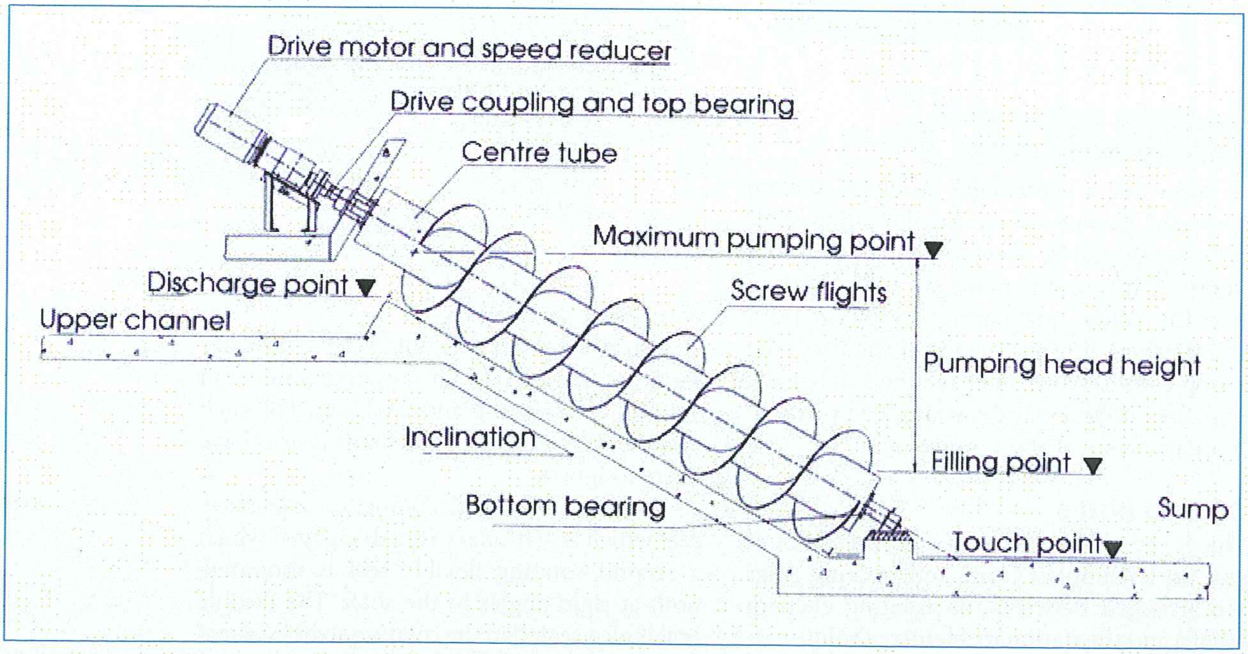
Two special pumps

In the water industry, the variety of pumps, their applications and combinations, and use in conjunction with other mechanical/electrical equipment make it possible to find the best and most cost-effective solution for every need. Other equipment includes mixers, blowers, aerators, diffusers, ejectors etc. Two other special pumps should be mentioned.

The Archimedean screw pump

These pumps are used to lift large volumes of water over short distances to a higher level. They do not clog easily and are thus also often used at the inlet of a wastewater treatment plant to pump raw sewage.

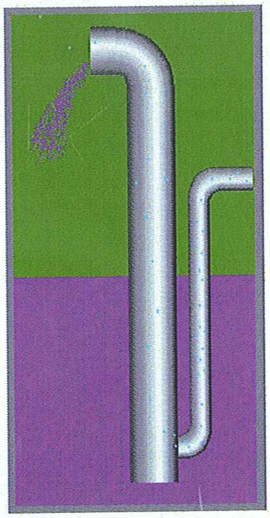
Cross section through an Archimedean screw pump



The airlift pump

The airlift pump is based on the principle that a mixture of air and water is less dense than water alone. Airlift pumps have no moving parts and are operated by a supply of pressurised air. They are often used to remove grit and sludge. Their efficiency is quite low, but they have extremely low maintenance costs.

In an airlift pump compressed air is piped down a shaft. The air then returns up a large diameter discharge pipe carrying an air-water mixture. The compressed air aerates the liquid in the discharge pipe, lowering its density. As this mixture is lighter that the surrounding water, the fluid mixture is forced upwards. Airlift pumps have no moving parts except the compressor or blower which is located outside the pumping area.



The operating principle of an airlift pump

Stuffing boxes and mechanical seals

In order for a centrifugal pump to operate correctly, it is necessary for the pump shaft to be sealed where it enters the volute of the pump. If this seal is poor, air will be drawn into the volute, preventing the pump from priming and diminishing the efficiency of the pump considerably. Shaft sealing is normally done by either a gland packing or by one or more mechanical seal arrangement.

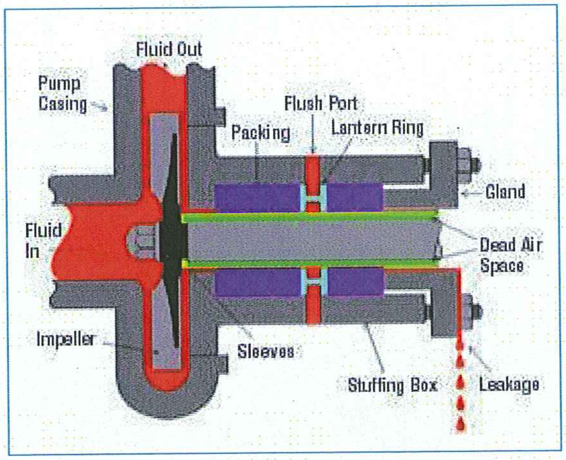
Stuffing boxes

This is the oldest and most common form of seal. In its simplest form, soft packing rings are arranged between the rotating element (shaft) and the stationary element (volute casing). When the pump is operated at a suction pressure below atmospheric pressure, some of the fluid pumped by the pump is tapped from the volute casing and fed via a lantern ring into the gland packing. Some of this liquid will leak back into the volute casing and some outward to atmosphere. This is important, as this liquid serves to lubricate and cool the packing rings continuously. If this fluid is not allowed to leak, heat due to friction will build up, causing the packing to burn. As the gland packing wears away due to friction, it can be adjusted to force the packing rings more tightly against the shaft. When they are no longer able to be adjusted without serious leakage, they should be replaced.

Stuffing boxes with gland packings have the following limitations

- they cannot pump liquids with high temperatures
- the pressure they can operate at is limited
- the rubbing speed between the shaft and the packing has limitations.

Packings are manufactured from a variety of materials such as graphite, PTFE, etc.



Cross section of a stuffing box and lantern ring on a centrifugal pump

Illustrations on this page from the Internet

Mechanical seals

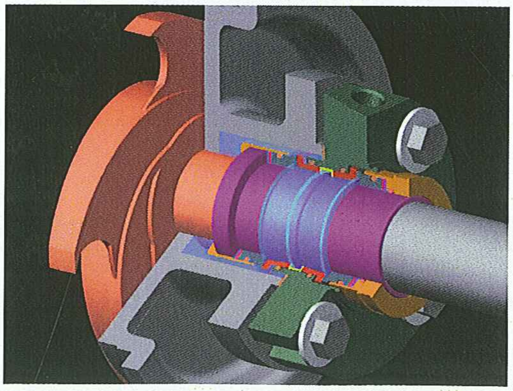
Sometimes it is not desirable to have the leakage which is required for the successful use of stuffing boxes and gland packings. For such cases, a large variety of mechanical seals have been designed.

A mechanical seal comprises a primary seal which is stationary (fixed), against which a second rotating flexible seal is mounted, both at right angles to the shaft. The flexible seal is also sealed to the rotating shaft by a secondary seal. A continuous force from a spring is then applied to the rotating element to keep the faces of the stationary element and the rotating element against each other. In addition, the pressure inside the pump volute also acts with a force on the mechanical seal, helping to ensure contact between the two rubbing faces. All mechanical seals depend on a thin film of liquid between the rubbing faces of the two elements. This implies that there is again leakage to the atmosphere. However, in a well designed seal, this leakage is so small it usually evaporates before droplets are formed.

Mechanical seals are sometimes mounted in a double seal configuration when highly flammable fluids or toxic fluids are pumped. Pumps need to be specifically designed to utilise a mechanical seal. In applications where abrasive liquid such as silt laden water need to be pumped, pumps are designed with special ports to enable continuous flushing of the mechanical seals to prevent a build up of abrasive materials on the seal faces.

Mechanical seals are also preferred for clean water applications.

A mechanical seal
Illustrations this page Internet



Cross section showing a pump shaft fitted with a mechanical seal *(blue in the illustration)*

Couplings and alignments

The purpose of a coupling is to connect the prime mover (motor or engine) to the driven item (pump, conveyor, gearbox, etc.). A coupling also absorbs shock loads imposed on the motor, adjusts to minor misalignments and allows separation of the prime mover and driven unit from each other for maintenance purposes.

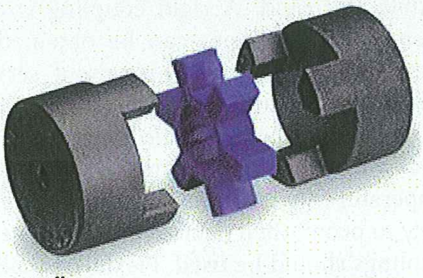
There are two basic types of couplings; flexible and rigid. A rigid coupling is used when exact alignment can be obtained on fitting and maintained throughout service. Non-alignment in service may be caused by settling of foundations, deflection of support, shock loading, wear of bearings, vibration and temperature fluctuations. If any of these are likely to occur, then flexible rather than rigid couplings should be used. Flexible couplings can be classified as follows

- Torsionally soft couplings using a rubber element or bush
- Torsionally stiff couplings, such as gear couplings.

The softer couplings act as shock absorbers and absorb the forces generated by abrupt changes in pumping speed. A typical example of a popular flexible coupling is what is known as a Fenaflex Tyre Coupling. It consists of two metal discs between which a rubber element or 'tyre' is clamped. The metal discs fit over the pump and motor shafts, and are tightened using a keyed taper-lock connection. The shaft alignment is then conducted, aligning the two metal discs and then the 'tyre' is clamped between the discs to take up torsion differences.

A torsionally soft coupling

A more rigid type, but also classified as flexible, is the 'jaw coupling'. It consists of two halves that each have a set of course splines or 'jaws' which fit into each other. Contact between the two sets of jaws is prevented by means of an elastic separation element. The materials used to manufacture these couplings vary from elastomeric polymers to steel, depending on the torque requirements of the application.



A jaw coupling
Illustrations on this page from the Internet

The importance of alignment

The biggest contribution maintenance staff can make to lower the operational costs of any rotating equipment, including pumps, is to ensure the alignment between the rotating equipment and the motor or engine is correct from the start. When misaligned, the loading on shafts increases dramatically due to the reaction forces created within the coupling.

The alignment of a pump and motor unit is thus very important, as misalignment can cause the following problems, which all lead to increased operational costs

- bearings and couplings run a lot hotter than they should
- vibration becomes excessive
- bearings, shafts, seals and couplings will fail prematurely
- power consumption increases significantly.

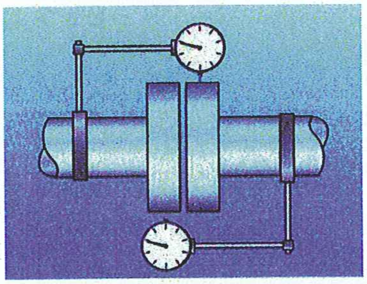
It is thus a good idea to have the alignment on pump units checked at least once every six months.

Studies have proved that even a small misalignment on pump unit shafts can increase electricity consumption by 8–10 %. Given that on some water treatment plants there are quite a number of pumps, this could have a significant impact on electricity consumption and costs, over a period of a year. Similarly, it has been proved that a small misalignment can reduce the service life of a mechanical seal by up to 90 %.

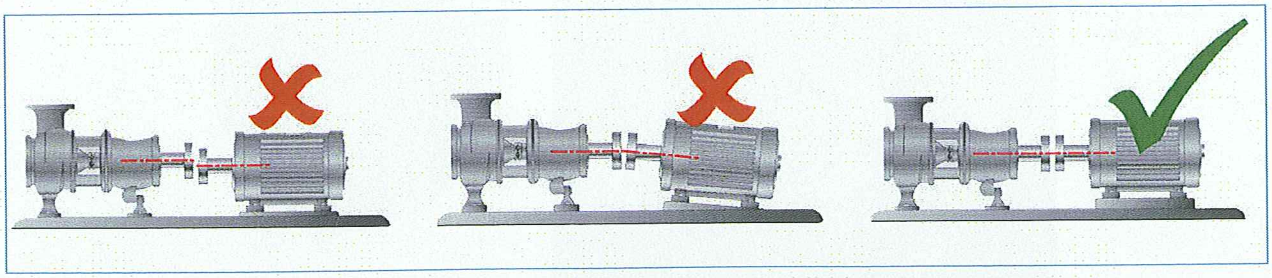
The most common alignment methods employed are the following

- The straight edge and feeler gauge method – oldest, most common method, but inaccurate
- The dial indicator method – better than above, but still reliant on human error
- Laser alignment – quick, accurate, and reliable.

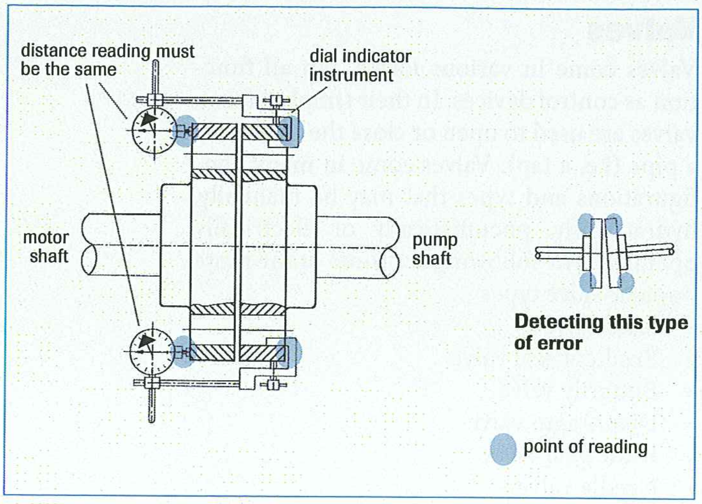
The straight edge and feeler gauge method is only accurate to roughly 0,1 mm (4 mils) while with the dial indicator method, accuracy of up to 0,01 mm (0,4 mils) is attainable. The laser alignment method is accurate to 0,001 mm (0,04 mils) but requires a high initial capital cost, as well as an investment in the training of staff to use the equipment to its full potential.



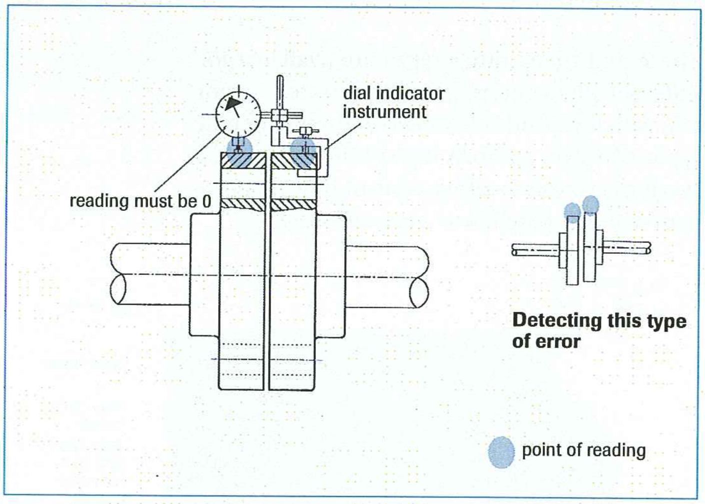
The dial indicator method



The incorrect and correct alignment of a pump and motor unit



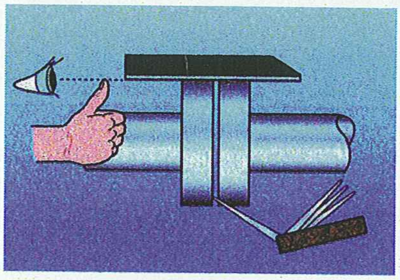
Checking the parallelism of axes (angular alignment)



Checking that the axes are parallel (shafts in line at coupling end).
Illustrations from Pumps Principles & Practice

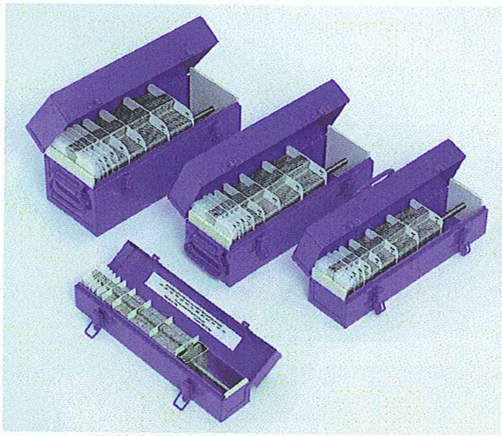
The straight edge and feeler gauge method

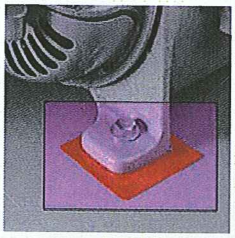
The straight edge is laid across the top of the flanges of the coupling hubs to determine vertical misalignment and then moved to either side of the flanges to determine horizontal misalignment. The feeler gauges are used between the flanges to measure angular misalignment. Shim thicknesses are then estimated and inserted under the motor pedestal feet and measurements are done again. This is essentially a 'trial and error' method. This method is most often used by municipalities as it does not require expensive equipment or highly technical training, but it is not the most accurate method and is reliant on the 'human factor' for its accuracy.

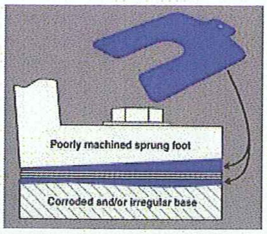


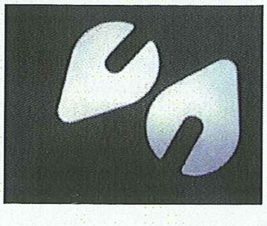
The straight edge and feeler gauge alignment method

A shim is a thin metal plate which can be inserted between the pump base plate, or a motor or pump mounting pedestal. By inserting a shim, small differences in misalignment can be corrected to prevent vibration. Shims are generally bought in a selection of thicknesses, with each shim's thickness etched onto it so that the fitter knows by how much he or she is correcting the misalignment. Shims can also be used in a combination of thicknesses to make up large deviations.









A selection of commercially available shims *(top)*, **typical shim application** *(middle)* **and typical shims used for alignment** *(bottom)*
Illustrations – Internet

learn more about

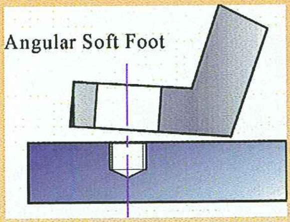
What is a 'Soft Foot'?

A gap between one foot of a machine such as a pump or motor and the concrete plinth or base plate that it is mounted on is known as a 'soft foot'. A pump or motor generally has four feet and usually rests on only three. This is primarily due to manufacturing inaccuracies when pump casing or motor casings are cast. Normally a geometric plane is determined by at least three points, which is why a dairy-farm milking stool has only three legs.

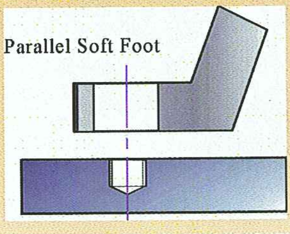
A 'soft foot' which is not shimmed will distort the pump or motor casing when the bolts that hold it down are tightened to secure it in place. This distortion will affect alignment, and tend to bind the rotating shaft and preload the bearings, which will cause premature failure.

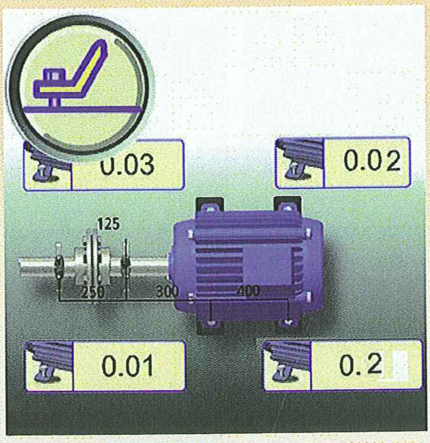
It is therefore vital to check for 'soft foot' BEFORE any alignment is measured and compensated for by inserting shims.

The figures show how to check for the two basic alignment errors that can be encountered.



Typical occurrences of 'soft foot'



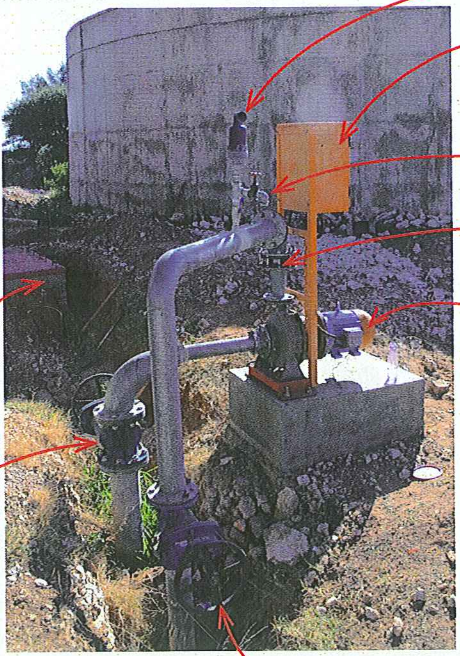


Valves

Valves come in various forms, but all function as control devices. In their simplest form, valves are used to open or close the flow from a pipe (i.e. a tap). Valves come in many configurations and types that may be manually, hydraulically, pneumatically or electrically operated. The following are some of the more popular valve types

- Gate valve
- Resilient seal valve
- Butterfly valve
- Diaphragm valve
- Knife gate valve
- Needle valve
- Non-return, reflux or check valves
- Air valves.

These and many other types are available for different applications. In a simple water system you will often find at least two to three different types of valves performing specific functions. In all cases, valves either control flow or pressure within a pipeline or pressure vessel.



A newly installed pump at the reservoir site in Hopetown as part of refurbishment of the water supply system. This installation has a monoblock pump, i.e. the pump and motor in a single unit. The installation also includes various types of valves. A steel cage must be mounted over the installation to prevent theft and vandalism.

Control valves

Control valves serve many functions in modern hydraulic applications, including

- Pressure reducing valves lower water pressure before it enters a reticulation network
- Pressure sustaining valves keep pressure constant when upstream pressure is fluctuating
- Flow control valves ensure a constant flow of water
- Level control valves control water levels, e.g. in reservoirs
- Non-return valves prevent the reverse flow of water, usually in conjunction with pump control valves
- Pump control valves are the most common pump station application *(see below)*
- Surge control valves relieve a surge/water hammer in a pipe system, e.g. caused by a power failure.

The pump control application works as follows. A pump starts and stops against a closed valve to protect the system from pressure surges. This can only be done with centrifugal pumps and not with positive displacement pumps. The pump starts with the control valve closed and after the pump reaches operating speed the valve opens slowly. This brings the system into operation in a controlled manner. The same is done when stopping the pump. The control valve will slowly close while the pump is running. The pump only shuts down when the valve is fully closed. This is a very effective method of controlling water hammer.

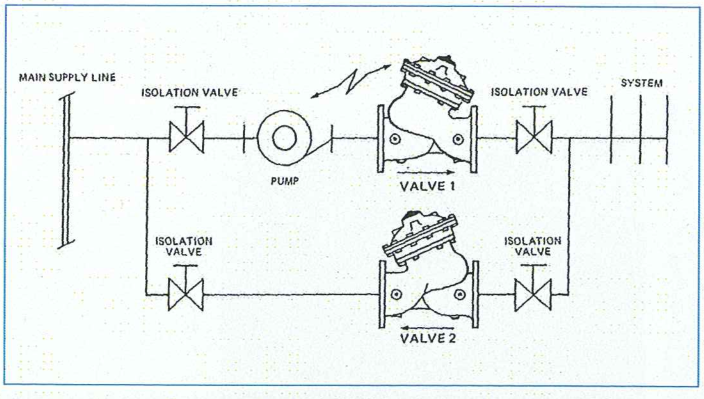


Diagram showing the operation of control valves. Valve 1 prevents pressure surges during starting and stopping. The pump and valve controls are synchronised to start and stop the pump, when valve 1 is closed. Should a power failure occur, valve 1 closes immediately. Valve 2 maintains a constant, preset upstream pressure independently of changing source potential and/or system demand. This controls water hammer.

From a maintenance point of view it is important to always keep these valves clean, especially the breather holes on the valves and the pilots, as insects can nest in these and interfere with the working of the valve. Always keep the settings on a valve as prescribed by the engineer or manufacturer. *(See box on next page).*

Air valves

The purpose of an air valve is to either release air which has become trapped in a pipeline or to allow air to enter a pipeline, should a vacuum occur. Air is typically released from pipelines on filling the pipe for the first time, and thereafter when air dissolves in the water and is released in low pressure areas.

An air valve consists of a float in a housing, which seals an opening under specific circumstances. The float is manufactured to have sufficient weight not to rise when air flows under and around it. When water under pressure, which has a much higher density than air, pushes against the float, it rises up in its housing and seals off the opening or orifice, preventing the water from escaping. A typical air valve has the following components

- air collection chamber or accumulator (normally a T-piece with a large diameter branch)
- riser (thinner pipe which is generally similar to the diameter of the air valve)
- isolating valve (small valve on the riser, which can be closed in order to remove the air valve)
- air valve.

Air valves are always located at the high points on a pipeline or where sudden changes in slope occur. When the gradient changes from positive to negative (uphill to downhill) at an apex point, when the gradient changes from negative to more negative (downhill to steeper downhill) and if a pipe continuously rises and falls, an air valve should be installed at least at 500 m intervals. There are two main types of air valves – single action and double action types. A single action air valve only allows trapped air to be released, while a double action air valve also allows air to enter a pipe when a vacuum occurs. A vacuum is defined as an area where the pressure is lower than atmospheric pressure.

A double action air valve

learn more about

The use of pressure sustaining valves

Keimoes water treatment plant also houses the clear/potable-water pump station, which pumps the treated water to two storage reservoirs in the town. The water reticulation system is a combined system, which means that the clear-water pumps pump directly into the network and the water which is not used by consumers ends up in the storage reservoir.

The other available system is the so-called isolated system, where clear-water pumps pump directly to a reservoir with no link to the reticulation system. The water is then fed into the reticulation network by a dedicated feed pipe using gravity to provide the pressure.

In many towns and cities an original isolated system was changed at some point to a combined system, to increase pressure in specific areas by connecting them directly to the pumping main. The downside of a combined system is that the pumping head varies continuously. When the demand in the town is high, there is a large abstraction from the network, causing the system pressure to drop. When this happens the pump automatically compensates in accordance with its characteristics, as found on the pump performance curve. This means that the duty point of the pump shifts to the right of the curve, causing the pump to cavitate and/or overload, as it is now trying to pump a higher flow than that for which it was designed.

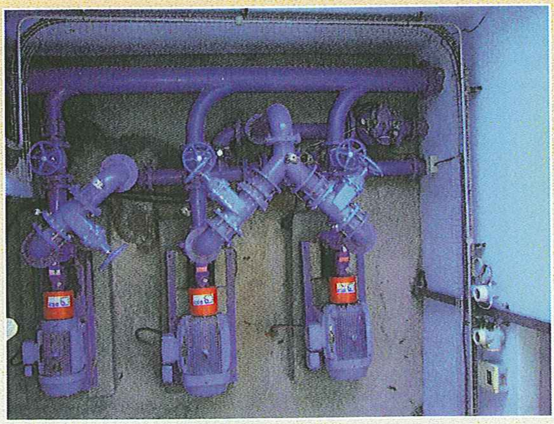
When the opposite scenario occurs, i.e. when demand decreases, the system pressure will increase and consequently the pumping head will also increase, leading to the pump duty point moving to the left of the performance curve and pumping less water, due to the increase in head.

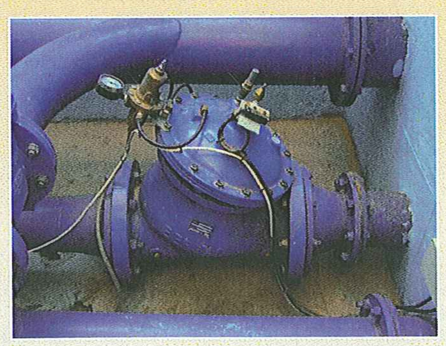
To control this phenomenon, pressure sustaining valves are used. A pressure sustaining valve is fitted with a pilot valve that continuously monitors the pressure downstream of the valve and then hydraulically opens or closes the main valve to maintain a constant pressure upstream of the valve. Pressure sustaining valves are thus installed on the pump delivery side, between the pump and the rising main. This valve then ensures that the pump is always pumping against a constant head and thus delivers a constant flow, irrespective of what happens in the reticulation network.

When a pressure sustaining valve is installed, the pilot valve is pre-adjusted until the pump is running exactly on its duty point. Should the downstream pressure decrease, the valve will close slightly to keep the upstream pressure constant, and vice versa.

When pumps do not operate on their duty points they will cavitate, experience excessive wear, trip electrical circuits due to overload, and cause premature failure of electric motors. Control valves that prevent such operational damage are expensive, but are a lot cheaper than continuous maintenance, premature replacement of pumps and motors, or modifying a network to function as an isolated system again.

Overview of the the main pump hall at the Keimoes water treatment works, with a pressure sustaining valve in the upper right corner. right Detailed side-view of the pressure sustaining valve.





A good quality air valve generally has two orifices for releasing air. The large oriface opens during the initial filling of the pipe when rapidly approaching water in the pipe displaces large volumes of air. The smaller orifice operates when the pipe is full and at operating pressure, continuously venting small quantities of air entrained in the pipe due to pumping, etc.

When a pipe is drained, normally at a scour valve located at a low point in the pipeline, water flows away from the high point, causing a vacuum in the pipe. When this occurs, the air valve should open, allowing air to rush into the pipe to prevent the vacuum from imploding the pipe walls. This phenomenon also occurs when surges such as water hammer occur.

Telemetry requirements for pump stations

As water pump stations are often far from the treatment plant or control centre, the use of radio or hardwire telemetry systems is becoming evermore common. The increasing use of telemetry has lead to these quite sophisticated systems has led to increasingly affordable and easier to use. Nowadays, a pump station is considered a 'simple' telemetry installation and a telemetry unit controlling a pump station with two pumps can be purchased for roughly R30 000.

As a point of departure, a pump station telemetry system should control and/or monitor the following parameters

- Pump start, pump stop
- Pump ready
- Pump tripped
- The availability of electrical power
- Pump station security.

In addition to the above, depending on the instrumentation installed at a pump station, telemetry systems could monitor and provide instantaneous feedback on

- Flow leaving the pump station (if fitted with a compatible flow meter with an analogue output)
- Pressure generated by the pumps (If fitted with a pressure transducer with an analogue output)
- Total volume of water pumped (if fitted with a compatible flow meter with a digital pulse output)
- Pump sump or reservoir level (if fitted with either an ultrasonic level sensor or differential pressure sensor with an analogue output).

Depending on the equipment, intelligent telemetry can control a pump station automatically. For example, a receiving reservoir fitted with a level sensor and telemetry outstation could control a pump station automatically. The system could be programmed to monitor the reservoir level and switch the pumps on at a preset reservoir level and switch them off when the reservoir reaches its full level. To make this possible, both the reservoir and pump station must be equipped with a telemetry station.

Operational personnel should never trust a telemetry system blindly, and operational procedures must be put in place to force operators to monitor telemetry outstations on a regular basis, to ensure that they are responding correctly.

Telemetry stations should preferably be run off a mains power supply, but can be powered by a solar installation where no mains supply is available. *Read about telemetry systems in Booklet 12.*

learn more about

How to close and open a gate valve

To avoid water hammer, gate valves must be closed and opened slowly and carefully.

During the manual closing of the valve the hand wheel (or the T-key) is turned clockwise until it is completely closed. It should not be closed beyond the maximum operating torque, therefore the wheel should be turned back just half a turn (180 degrees). The same applies when opening the valve. Turn the wheel anti-clockwise until it is fully open, and then turn the wheel clockwise just half a turn.

Remember to close and open a gate valve slowly – one 360 degree turn in about 20 seconds. This is especially important on big valves, 250 mm and larger. These need about 10 minutes to open or close.

A confusing fact is that in old networks there might still be valves that are closed by turning the hand wheel anti-clockwise. They should be replaced, wherever possible, by valves that are closed by a clockwise movement. This should be the standard in all networks.

Why such a difference in O&M?

– a question at Vanderkloof

There are two pump stations in Vanderkloof, a town near the great dam in Renosterberg Municipality.

The one at the huge Vanderkloof dam is managed by DWAF, and pumps raw water to the nearby (just over the hill) Renosterberg Municipality Water Treatment Works. The pumps run almost 24 hours a day, pumping about 50 litres per second, or between 4 000 and 5 000 m³ per day.

The other pump station at the municipal water treatment plant pumps treated water to Vanderkloof, and to Petrusville, some 17 km away. It used to be managed by DWAF but in 1994 it was handed over to the municipality and its technical department.

On visiting the two pumping stations you immediately notice huge differences in their operation and maintenance. One is so clean and tidy you could eat your breakfast on the floor. All pumps are shining and running. The other is dirty and messy, and pumps are leaking or broken. Parts of the station look more like a scrap yard.

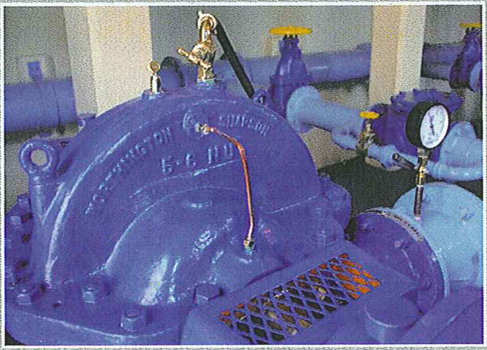
In the tidy one, there are strict schedules for how the O&M should be done. Daily maintenance includes keeping the place clean and tidy, and checking the grease on motor bearings and gland packings on the pumps. Once a week an electrician checks and cleans the slip rings on the motors. Once a year the motor brushes are replaced.

The pumps in this pumping station were installed in 1975, and they are still running! Over more than 30 years, only minor reconditioning has taken place – only the bearings on one motor and the impellors on one pump have been replaced.

At the other pumping station the operator reports that it is difficult to get cleaning materials.

In the shining pumping station O&M is properly planned and budgeted, staff are knowledgeable and skilled, and committed leaders supervise the O&M diligently.

The two pumping stations are neighbours and both are public sector infrastructure assets, built with tax payers' money to serve communities and the wellbeing of citizens.



The two pump stations in Vanderkloof – one with high-quality O&M *(above)*, **and the other, in desperate need of proper O&M** *(below)*

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After long periods of operation, connecting bolts should be checked for tightness, and this should be done more often if there is vibration in the pipeline.

Control valve maintenance is more complex, and even for routine maintenance on a control valve it is important that the service technician has a thorough understanding of the fundamental construction and operation of the valve. Fortunately, control valves require a minimum of maintenance. A periodic inspection schedule should be established to determine how the flow and suspended particles (if applicable) are affecting the valve. After about three years of operation, replacement of important parts and the diaphragm is recommended.

learn more about

Air valve maintenance

An air valve is a rather sturdy piece of equipment with basically only two things that can go wrong and prevent its continued operation

- a blocked orifice
- a stuck float.

It is therefore advisable that air valves be maintained and checked for successful operation at least once every six months, but preferably every month. This could typically be done by having a set of replacement valves in supply and then say removing 5 of the installed valves at a time in winter, when the demand on the pipeline is lower.

When the air valves have been removed, it is good practice to take them to a workshop where they can be dismantled in a controlled environment. Some types have small parts and springs which may pop out and get lost when doing this in the field.

Dismantle the air valve, clean out any debris, slime and dirt that has collected over time. When all parts have been cleaned, they may be lightly lubricated with a light machine oil before assembling all the parts again. Should the outer casing show any signs of corrosion, this may be removed by sanding with course sandpaper and recoated with a suitable epoxy coating.

On completion of these tasks, the valves may then be refitted in their original positions and the replacement valves moved onto the next series of air valves.

Pump station and surroundings

This section deals with the bare minimum requirements for a pump station. The items described are necessary for the correct operation of any pump station, and facilitate maintenance of the equipment, to ensure it achieves its designed lifespan.

1. Pumps should always be installed in a ***pump house*** which may be constructed of brick, concrete or even expanded metal cages. A pump house is not a necessity but for a permanent installation, it protects the pumps, motors and switchgear from the elements and prevents vandalism and tampering. The level of importance of a pump station will dictate what measures are needed to secure it. Try to always provide sufficient space in a pump station. There is nothing more difficult than trying to remove a heavy pump or motor from a confined space. Leave at least 1 to 1,5 m free space around pumps and piping. Another feature that will make O&M easier is a crawl beam above the pump and motor assembly.

2. It is important to always have an ***isolation valve*** on the upstream and downstream side of the pump, so that the pump can be removed for maintenance if necessary. In addition (although not the preferable way), valves can also be used to control pump delivery and ensure that pumps operate at the correct duty point.

3. Note the ***reducers*** before and after the pump. This component joins the pipe diameter to the pump inlet and outlet size. Pumps often have smallish inlet and outlet diameter connections. Small diameters have small cross sectional areas which cause high velocities. Intake or suction velocity should be limited to no higher than 0,75 m/s to 1 m/s maximum. Inlet reducers should always be of the eccentric type to prevent air being trapped in the suction piping. Similarly, discharge velocities should be limited to roughly 1 m/s to 1,5 m/s. These velocities are attained by choosing suitable pipe diameters which are often larger than the connecting diameters of the pump casing.

4. Each pump set must have a ***non-return valve*** to prevent the duty pump circulating water backwards through the standby pump. In addition, a non-return valve prevents the discharge pipe from emptying every time the pump is switched off. Non-return valves also play a major part in the handling of water hammer.

5. An ***air valve*** is always installed at the highest point on the delivery side of the pipeline to release any air that moved through the pump.

6. It is always good practice to install a ***flow meter*** in all pump stations as this allows you to monitor delivery in different time periods. In addition, it allows the operator to see whether the pump is operating at its specified duty point. Flow meters usually have a totalizer function which records the total volumes that have been pumped. This information is useful in the case of a water balance and also if the owner of the pump needs to pay for the water abstracted.

7. Another very important way to monitor pump performance is with ***pressure gauges***. Always install a pressure gauge on the delivery and suction sides of each pump set. The delivery pressure gauge together with the flow meter is essential to ensure that the pump is being operated at its specified duty point. The suction pressure gauge measures either a vacuum in the case of a negative suction configuration, or the suction head in case of positive suction configuration. This inlet pressure also determines the performance of a pump.

8. The Electrical Drawing should show details of the construction of neat cable trenches and emergency stop controls. It is always good practice to leave a laminated copy of the ***electrical switchgear circuit diagram*** in the switchgear enclosure. This is a valuable tool when an electrician needs to do fault finding on the switchgear. It is required by law that an ***emergency stop button*** be installed for any rotating equipment when the switchgear is further than 1,5 m from the rotating equipment. This emergency stop switch can be activated when something gets caught in the rotating elements and it can also be engaged to ensure equipment is shut down when maintenance is done, to prevent someone starting the equipment while people are working on it.

9. Also note that large ***access doors*** allow a vehicle to enter to pick up the pump or motor. Depending on the size and weight of the equipment, this is very important.

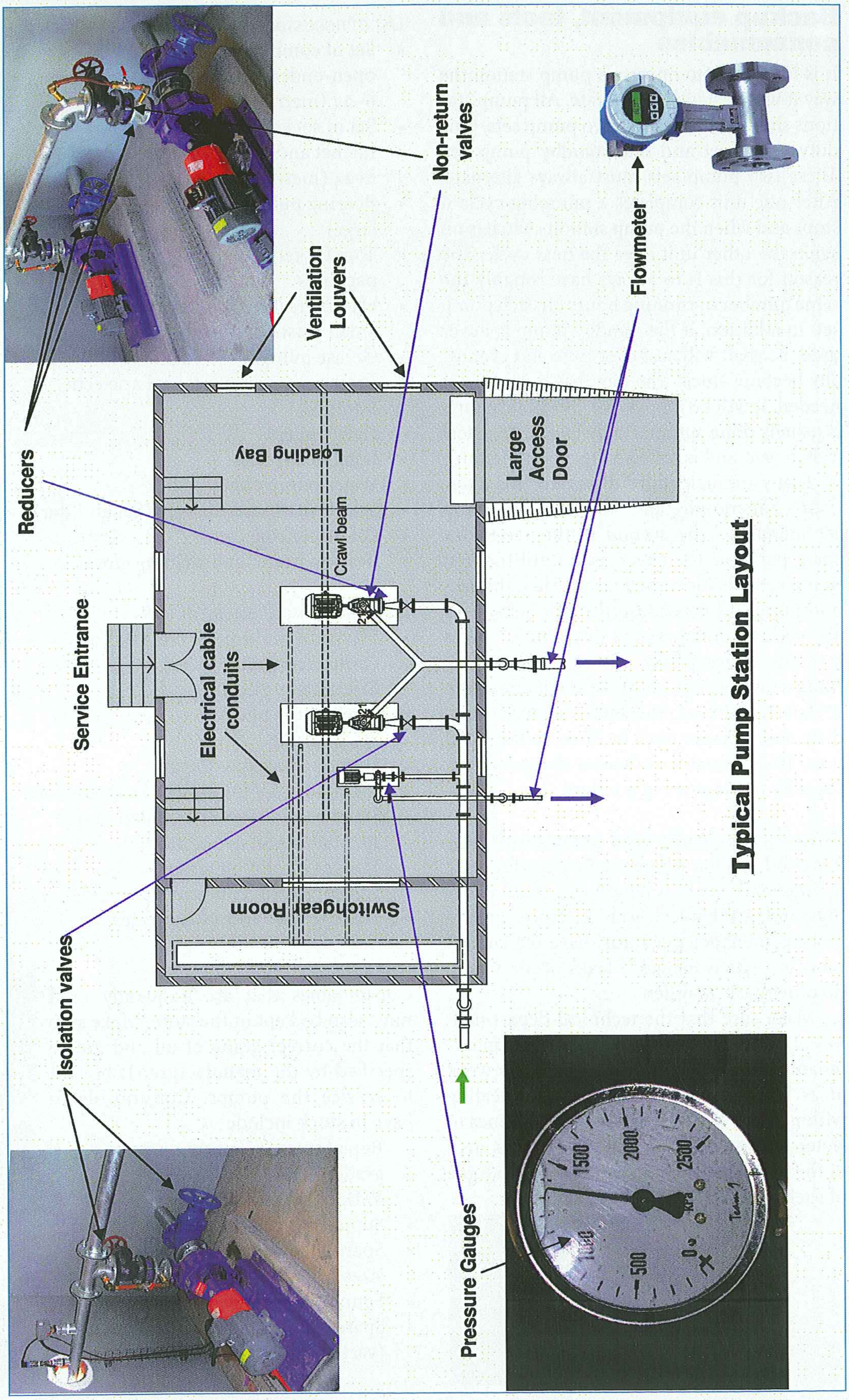
10. The pump station surrounding area should be ***fenced off*** with an access gate that is always locked, to keep the public out. This is important for their safety and protection of the pump station.

11. Always make sure that the pump station has adequate ***lightning protection*** to protect sensitive electronic equipment from direct strikes and induced voltage spikes that may occur during thunder storms.

12. Ensure proper ***ventilation*** of the pump house. Electric motors are not 100 % efficient and always lose some degree of energy in the form of heat. Especially in the Northern Cape where high ambient temperatures are experienced, adequate ventilation is a necessity. Electronic switchgear such as soft starters and variable speed drives often have temperature limits within which they can operate. Sometimes it is even required that air-conditioning be installed to ensure suitable operating conditions for this equipment. When fresh air louvers are installed, remember to have them fitted with insect gauze on the inside. This keeps insects as well as small reptiles such as geckos and lizards out of the pump station.

13. Keep the pump house/station ***clean***. Remove rubbish and insect nests. Always clean up spilt oil and grease from floors and pump plinths after services.

14. Keep the pump house/station area clean and tidy and do not leave old consumables, rags and oil cans lying around. It creates a poor impression.



Typical Pump Station Layout

Backup equipment, tools and consumables

It is important to operate a pump station the way it was designed to operate. All pump stations should have at least two pump sets. One duty pump set and one standby pump set. These two pump sets must always alternate. After one unit completes a pumping cycle it stops and when the pump station switches on again the other unit does the next cycle. The reason for this is to always have roughly the same number of running hours on each pump set. In addition, if the standby pump is never used, its shaft will rust over time and eventually become stuck. The day that the pump is needed, it will be inoperable. This alternating is usually done automatically by the electrical switch gear and is called a flip-flop function.

Many municipalities disregard this alternating functioning and run only one pump set manually. The second is then used for spare parts or it is never used until the first pump set fails for some reason. Then the second pump set is used until it also fails, usually without doing repairs to the first. This is a totally unacceptable operating procedure. Pumps must always alternate and if one pump set fails the second must take over and immediate maintenance must be done on the failed unit. This ensures that there is always backup capacity in the event of a failure.

Spare parts, tools and consumables

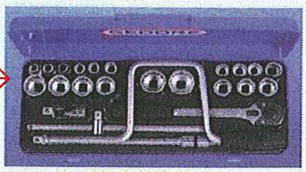
It is good practice to keep spare parts for basic maintenance such as couplings, gland packings and mechanical seals in store. Ensure that maintenance personnel have the correct tools to tighten flanges if leaks occur and to do other basic maintenance.

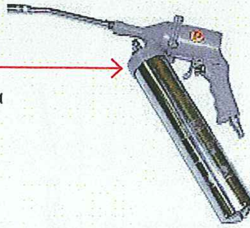
Make sure that the technical department has at least one mobile petrol-driven maintenance pump to empty manholes or work areas. This is especially important for dealing with pipeline failures, where large volumes of water have to be cleared to get to the source of the problem. The photo shows an example of such a pump.

Mobile pump

List of necessary mechanical tools

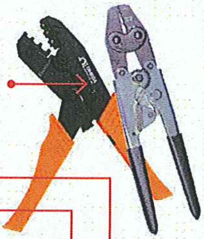
- Set of combination ring/ open-ended spanners, sizes 6–24 (metric)
- Set of sockets complete with ratchet and power bar sizes 6–24 (metric)
- Bearing pullers (small to large)
- Tool for removing and inserting gland packings
- Hammers (small to large)
- Small plastic funnel for oil
- Grease pump
- Spare pressure gauges and a selecti fittings
- Heavy pliers
- Long nose pliers
- Water pump pliers
- Selection of screwdrivers (flat and star)
- Oil dispensing can
- Bearing heater and welding gloves.





List of necessary electrical tools

- Electrical multimeter (Amps, Volts, Ohms, continuity tester)
- Electricians pliers
- Side cutting pliers
- Wire stripper
- Selection of screwdrivers
- Crimping tool for lugs and terminations
- Set of combination ring/open-ended spanners, sizes 6–24 (metric)
- Megger insulation tester
- Soldering iron and resin core solder
- Small blower and vacuum cleaner.

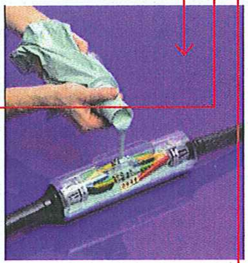


Consumables to have in stock

Consumables that are frequently used must also be kept in the store. Make sure that the correct grade of oil and grease specified by the manufacturer is bought to service the pumps. Consumable to have in stock include

- Replacement oil of the correct grade
- WD40/Q20 lubricant
- Supply of grease
- Spare shaft couplings (various sizes)
- Fenner flex (various sizes)
- Spare gland packings (various sizes).

- Grease nipples
- Rags to wipe off excess oil and grease (don't use waste cloth)
- Fuses (selection of various types)
  - Spare light bulbs and fluorescent tubes (small to large various wattages)
  - Selection of bolts, nuts and washers
  - Selection of terminations, lugs, glands and cable jointing kits
  - Contact cleaner solvent
  - Silicone lubricant.



Pump maintenance and electrical maintenance

Most pumps require limited maintenance, if correctly selected and of sufficient quality. All pumps require at least **WEEKLY** attention. All pump stations should be inspected at least once a week, whether maintenance is required or not. Always follow the manufacturer's O&M instructions.

Maintaining a centrifugal pump

With conventional centrifugal pumps, the following minimum **WEEKLY** maintenance is required

- ☑ Check oil level
- ☑ Check condition of gland packing and adjust to provide a steady drip
- ☑ Lightly grease the threads of the gland follower studs with a copper coat or water-resistant grease
- ☑ Check tightness of the base plate mounting bolts
- ☑ Check for abnormal vibration
- ☑ Check for abnormal temperature
- ☑ Listen for any strange noises (bearing whine or cavitation)
- ☑ Start the pump and monitor the full load current
- ☑ Check operating pressures on the delivery pressure gauge
- ☑ Check the alignment on the motor shaft to pump shaft coupling
- ☑ Check the condition of the coupling and coupling guard
- ☑ Check the operation of the non-return valve (failure of this valve can result in a sheared pump shaft)
- ☑ Check operation of the motor cooling fan
- ☑ Check the mechanical seals for leakages.

Although the heading above refers to centrifugal pumps, these maintenance actions are fairly generic to most types of pumps, including positive displacement pumps.

Electrical maintenance

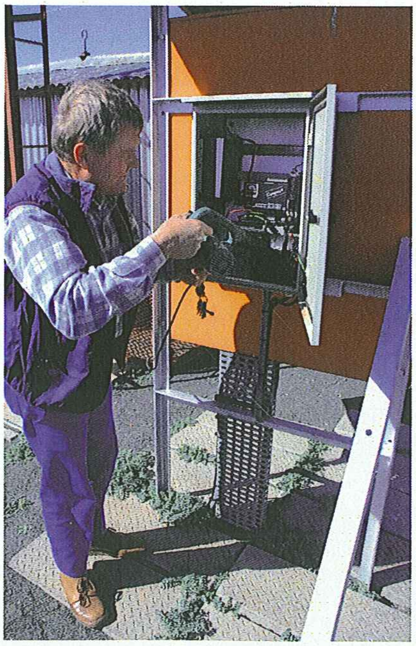
Every municipality that has pump stations powered by electricity should have either an in-house maintenance electrician or an arrangement with a private contractor to conduct regular preventative maintenance. A maintenance electrician should visit all pump stations at least **WEEKLY** to do the following basic maintenance

- ☑ Check functioning of all starters, contactors, trip mechanisms and overloads, etc.
- ☑ Check over/under voltage relay operation
- ☑ Start the pump manually and check the operation of all instruments, such as ammeters and voltmeters
- ☑ Check that all panel lamps and site lights are working
- ☑ Check the operation of the level control system, if the pump station is equipped with one
- ☑ Check operation of the telemetry system (if installed)
- ☑ Listen to all motor bearings for excessive wear (a worn bearing makes a cyclic whining noise which can be heard by putting your ear against a screwdriver which is touching the bearing housing)
- ☑ Clean off the distribution and control panels.

General quarterly electrical maintenance

In addition to weekly inspections, the following should be done **EVERY 3 MONTHS**

- ☑ Clean all enclosures thoroughly by washing down with a wet cloth on the outside and blowing out all dust, spider webs and insects on the inside with an electrical industrial blower
- ☑ Remove and clean all contactors with a solvent approved for electrical components
- ☑ Tighten all cable glands
- ☑ Ensure that cables are properly secured on cable racks and in conduits
- ☑ Check all terminals for integrity, signs of corrosion and 'hotspots'
- ☑ Clean level sensors and check settings
- ☑ Check and tighten motor terminals
- ☑ Grease all motor bearings
- ☑ Check all earthing systems and lightning arrestors for correct functioning, and replace if faulty.



Preventative maintenance on all electrical installations is mainly to keep cabinets and contactors clean, and to tighten all main current-carrying terminal points. Chris Hendricks, from Emthanjeni municipality, blowing out all dust from a telemetry cabinet.

Maintenance of other equipment

Although this booklet deals primarily with pumps and drives, there is often additional or special equipment at either pump stations or treatment plants that also requires care and maintenance to ensure its continued operation and reliability.

This section gives a basic introduction to such equipment and its minimum maintenance requirements.

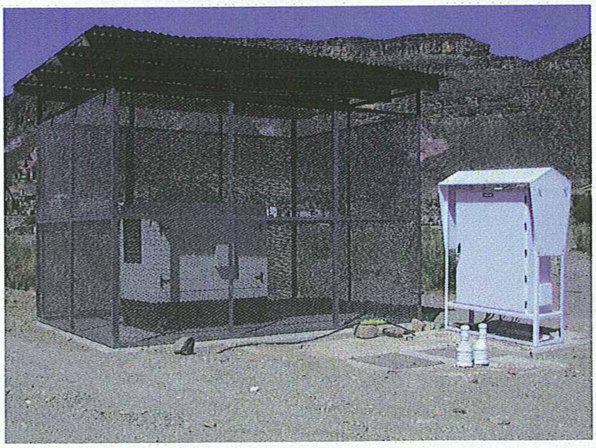
Generators and backup power supply

Although not that common in the Northern Cape, one does sometimes find that critical pump stations or treatment plants are equipped with a backup diesel generator to ensure an alternative electricity supply during periods when the mains supply is interrupted.

A generator consists of an engine (usually diesel), a fuel tank, an alternator, a control system and circuit breakers, and is usually mounted on a metal skid or inside a noise-suppressing, weather proof enclosure. Extras sometimes fitted to generator sets include Automatic Transfer Switches, Automatic Mains Failure Panels and remote control systems which operate through mobile cellular networks or by dedicated radio telemetry.

Like a vehicle, a generator needs to be serviced. A diesel powered car running at 1 500 rpm in 5th gear at 100 km/h for 100 hours will cover a distance of 10 000 km. Therefore if a generator has run for 100 hours at 1 500 rpm, it has essentially covered the equivalent of 10 000 km, the standard distance at which diesel cars are serviced. The working and required maintenance of diesel engines is covered in detail *on page 20, in Booklet 6.*

The alternator is the component that produces the electrical power. A rotating magnet (rotor) turns inside a static conductor (stator), causing a magnetic field to move across the conductor and generate an electrical current. The conductor is essentially coils of copper wire wound around an iron core. The maintenance on the alternator is usually limited to the alternator bearings. These should be greased on a weekly basis and replaced when they become noisy.



Many municipalities are forced to invest in standby generators because of the many electricity breakdowns or outages on the national grid. However, a water supply system should be designed to have at least a 24 hour storage capacity to cater for such events. A generator at the Hopetown water treatment works *(top)*. **A well protected backup generator at the Vioolsdrif border post pump station** *(middle left and bottom)*. **Many generators are placed in the open without any protection from dusty winds, seriously reducing their life span** *(middle right)*.

The control panel consists of an array of gauges, relays, switches and buttons used to control the functions of the generator set. Nowadays these control panels have become digital and have reduced considerably in size and increased in functionality. Besides a regular wipe with a damp cloth to keep the panel clean, other maintenance and repairs should be conducted by specialists, as these systems have become very complex. Attempting repairs may result in more damage than that which has occurred due to a malfunction.

Generators should be started regularly in order to test their functionality, but also to allow the starter battery to be charged. It is good practice to start the generator at least once in 14 days and then allow it to run for at least an hour under full load. Fuel, oil and coolant levels must be checked at least weekly as a matter of routine.

Transformers

A transformer is an electrical device that converts electricity of one voltage into another voltage, in a ratio similar to the ratio of the number of windings between the primary and secondary coils of the transformer. You see transformers of different sizes in electrical substations (sometimes at the top of utility poles), or converting the voltage to run a toy train set or computer, or to charge a cellphone.

Basically, a transformer converts electrical energy from high to low voltage using two properties of electricity. In an electric circuit, there is magnetism around the conductors. Whenever a magnetic field changes (by moving or by changing strength) a voltage is produced. Voltage is the measure of the strength or amount of electrons flowing through a conductor, measured in Joules per second or volts. If there's another conductor close to an electric current that is changing, an electrical current will be induced into that conductor as the magnetism changes.

A transformer takes in electricity at a higher voltage and lets it run through a series of primary coils wound around an iron core. Because the current is alternating continuously, the magnetism in the core is also alternating. Also around the same core there is a secondary coil with fewer windings. The magnetism changing back and forth induces a current in the secondary coil. Having fewer windings means less voltage. In this manner the voltage is 'stepped-down'.

This process also generates heat, due to the electrical resistance of the conductor material to the flow of electricity. Transformers thus need to be equipped with a cooling device or some form of heat dissipation. Typically this is done by filling a transformer with a special oil which has both cooling and insulation properties. On large transformers the hot oil is passed through a series of cooling tubes with a large surface area to allow increased radiation of the heat. Some transformers even have secondary air or water cooling systems to release this heat buildup.

A sealed ground-level transformer under construction, with incoming high voltage cable connections on the left. Four double outgoing cables on the right are assembled into two bundles as they go underground. Blue, yellow and red are the three live phases, while black is neutral. The white features on the left are surge arrestors. Above them are the brown bushings connecting to the primary coil inside the transformer. There will be a cable between each of the arrestors and the bushings to complete the connection. The 22 kV and 33 kV (22 000 and 33 000 Volt) markings on the side indicate that it is a dual-ratio transformer.

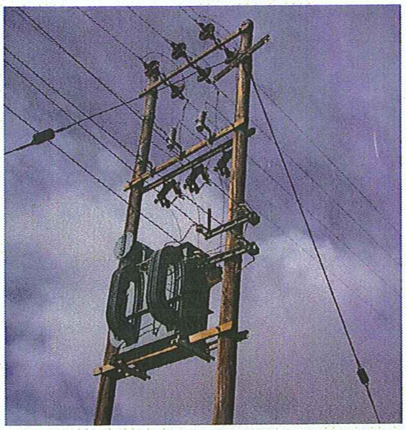
This is good engineering because in future it may be necessary to upgrade the feeder from 22 to 33 kV as the load increases over time, due to additional demand or expansion of the area that the transformer will serve.

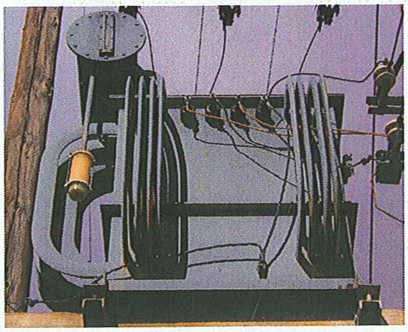
There are basically two types of transformers – sealed transformers, and so-called 'open' transformers. The difference is basically that the oil surface of an open transformer is equipped with an atmospheric breather pipe to allow gasses to escape from the transformer casing and air to enter it. The end of the breather pipe open to the atmosphere is equipped with a moisture trap, which is essentially a glass canister filled with silica gel.

Silica gel is a granular, vitreous, highly porous form of silica made synthetically from sodium silicate. Despite its name, silica gel is a solid. Silica gel's high surface area (around $800\,m^2/g$) allows it to absorb water readily, making it useful as a desiccant (drying agent). When a visible indication of the moisture content of the silica gel is required, ammonium tetrachlorocobaltate (II) or cobalt chloride is added as an indicator. This causes the gel to be blue when dry and pink when hydrated. This characteristic makes it an easy visual check of moisture content in the tranformer oil.

A sealed transformer is totally sealed. If it develops an oil leak, it needs to be replaced as no maintenance can be done on it. The sealed units are a lot cheaper than open transformers. Sealed transformers can be reconditioned by specialist rebuilders.

Voltage can also be stepped up by reversing the input. The current or amperage is inverse to the voltage on a transformer. A high voltage usually has a low current and when stepped down, a large current (high amperage) becomes available.





A large pole mounted open type transformer. The close-up photo shows the breather pipe to the left with its moisture trap. The trap is a canister filled with silica gel. The gel is blue when dry and pink when hydrated. This transformer needs oil replacement and new silica gel. The moisture trap indicates that the cooling oil in the transformer contains too much water and its cooling ability is dramatically reduced.

learn more about

Transformers on the Electrical Grid

Let's look at the electricity that comes to your home. When electricity comes from a power generation plant it is stepped up into a very high voltage with a low current, to enable the use of thin conductors over long distances. High voltage lines can be as high 155 000 to 765 000 volts, to allow distribution over many hundreds of kilometres.

In order for your home to use the electricity, it has to be at a lower voltage than on the long-distance lines, so it is 'stepped down' to a lower voltage by transformer. This lower voltage electricity is connected to the local electrical reticulation system at a substation. The substation reduces and distributes the large amount of electrical power in smaller quantities at lower voltage. It is then stepped down again and again.

Once smaller transformers take that voltage down to usually 6,6 kV or 2,2 kV, the power leaves the substation via the local distribution network, which may be either overhead on poles or pylons, or below ground level via cables.

In your neighborhood, a transformer on top of a utility pole, or one connected to underground cables, transforms the 2,2 kilovolts into 220–240 volts. This is then connected to your home connection via three wires for single phase, or four wires for a three phase supply.

The supply wires pass through the electricity meter, which measures how much electricity you use. One of the wires is the ground or earth wire, and the other two are the live and the neutral conductors.

Some businesses use higher voltage power to run big machines, so they don't need to have the voltage reduced as much.

Service and maintenance of transformers

Like any other equipment, transformers also need to be serviced and maintained, otherwise serious incidents and reduced economic lifespans will occur.

Oil samples should be taken at least once a year and a visual inspection of the external appearance of the transformer should be carried out. Oil samples are taken by contractors or qualified staff. There are a number of things to look for on a transformer during a visual inspection

- oil level of the transformer
- color of the silica gel in the breather (silica gel absorbs moisture present in the surrounding air, to prevent it from contaminating the transformer oil)
- the operating temperature of the transformer
- visible oil leaks due to leaking connection packings.

Normally an oil and gas sample is taken to be analysed in a specialist laboratory. From the analysis the condition of the oil in the transformer can be established. Typically, an oil analysis will look at three basic parameters

- moisture content measured in PPM (parts of moisture per million parts of oil). Moisture should not exceed 20 PPM
- acid content (measured in milligrams of acid per litre of oil). Acid content should not exceed 0,2 mg/ℓ
- insulation capability of the oil (measured in kilo Volt Amp). Insulation capacity should not be below 50 KVA.

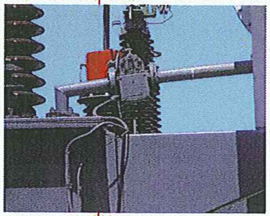
If any of these parameters are exceeded, the oil in the transformer needs to be replaced.

Most transformers are equipped with protection such as Bucholtz relay, which trips the high tension breaker if the oil level is low, if there is gas in the transformer or if overheating occurs.

Preventative maintenance of transformers

Municipal maintenance staff should on a three monthly basis conduct an inspection on transformers that includes the following

- ☑ Check operation of the high tension (primary side) circuit breakers by operating the breaker
- ☑ Check condition of surge arrestors and drop-out fuses
- ☑ Clean out all dust and magnetic debris around the HT cables between the circuit breaker and the primary side of the transformer
- ☑ Check and replace the cement mortar seal around the supply cable/soil interface
- ☑ Check bushings for cracks and leakage of oil indicating worn packings
- ☑ Check colour of the silica gel in the breather moisture trap
- ☑ Sample the oil (only on an annual basis)
- ☑ Replace oil when minimum parameters are reached
- ☑ Keep the transformer yard clean from weeds and rubbish.



Bucholtz relays should be checked for functionality every three months.

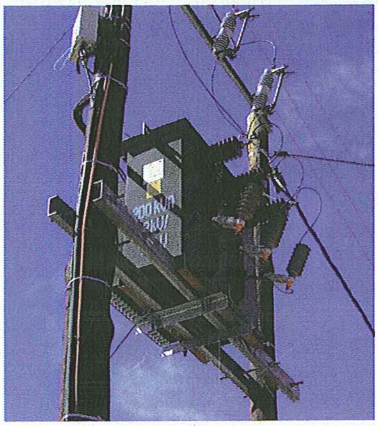
Onsite sampling and analysis of transformer oil should be done by a specialist, but it is the duty of the technical department to make sure it is done once a year.

Don't turn the transformer yard into a scrap yard! Keep it clean and the grass short, or a veld fire could destroy the transformer.

This is not a detailed description of transformer maintenance, but a basic guideline to make technical managers aware that such equipment does require regular maintenance.

Surge arrestors

A surge arrestor is a device used on power systems to protect other equipment from lightning and switching surges. A surge is a sudden and brief abnormally high voltage on a power transmission or distribution line. A surge arrestor is always installed before and parallel to the equipment to be protected and is connected to earth or ground by means of a conductor. When a surge or lightning strike occurs, the surge arrestor limits the voltage and diverts it to ground instead of allowing the high voltage to pass through to sensitive equipment, causing expensive damage. Once a surge or lighting strike has passed through the arrestor, it is damaged irreparably and needs to be replaced.



Drop-out fuses and surge arrestors on a pole mounted sealed transformer.

learn more about

How does the surge arrestor work?

At the heart of most surge arrestors is what is known as a Metal Oxide Varistor or MOV. MOV is a semiconductor that is sensitive to voltage. At normal operational voltages the MOV will act as an insulator and will not conduct any electrical current. When high voltages occur, such as caused by switching surges or lightning, the MOV becomes conductive and diverts the high voltage to earth. In simple terms it can be described as a very fast-acting electronic switch. At standard operating voltages it acts like an open switch and at high abnormal voltages it acts as a closed switch. A surge arrestor contains billions of Metal Oxide Grains that turn on and off in microseconds to form a current path from the top terminal of the surge arrestor to the ground terminal. A surge arrestor MOV of 35 mm diameter and height contains about 28 billion grains of metal oxide.

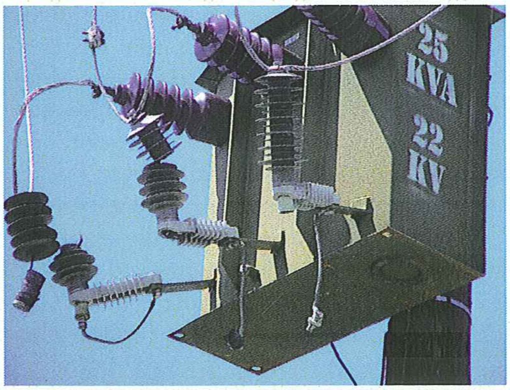
Surge arrestors are almost always installed in electrical power distribution lines to protect transformers, switchgear, telemetry systems or any other sensitive equipment. A surge arrestor can be likened to an insurance policy. As there is a 50% chance that it may successfully protect the downstream equipment, there is also a 50% chance that it may fail to do so. A surge arrestor only works once. Once a surge or lighting strike has passed through it, it is damaged irreparably and needs to be replaced.

Surge arrestor maintenance

Surge arrestors are **NOT** maintainable. However, it is good practice to conduct a visual inspection of all power line surge arrestors and pump station switchgear surge arrestors at least once every three months. Once a surge arrestor has blown, the downstream equipment will still function, but will have no protection if a surge occurs again.

Something practical to remember on overhead power lines is that the top connection of a surge arrestor to the power line should not be done with ACSR (aluminium conductor steel reinforced) but with a heavier gauge welding cable. The reason for this is that when a surge arrestor has functioned and failed, the top connector cable is normally burnt off by the high voltage passing through it. When ACSR is used for this connection it stays in position, and being high above the ground, the fact that the surge arrestor has failed is not visible. Welding cable is much heavier and when burnt off it hangs down, providing a visual indication that the surge arrestor has failed.

Further to the above, it is absolutely necessary that electrical maintenance personnel do a visual inspection on all their power lines prior to the rain season, when most lightning strikes occur. This is done by physically travelling along all power lines and visually checking the integrity of the surge arrestors installed.



A small pole mounted sealed transformer. The surge arrestors have been damaged by lightning and must be replaced.

22 KV indicates that the incoming high voltage supply is 22 000 Volt at roughly 1,1 Amp. The 25 KVA tells you that the transformer has transformed 22 000 Volt to 380 Volt at roughly 65,8 Amp.

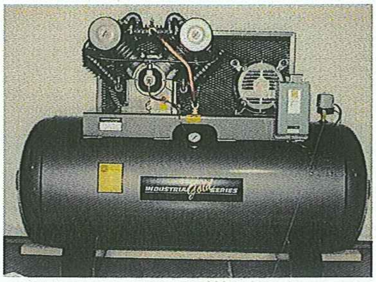
Compressors and air receivers

Both compressors and blowers are essentially air or gas pumps. A compressor pressurises small volumes of air or gas to high pressures, while a blower pressurises high volumes to moderate pressures. Compressors are usually equipped with a receiver tank which accumulates a volume of the pressurised air or gas for practical use.

Both these devices are often found at water treatment plants. Air blowers are almost universally used for backwashing gravity and sometimes even pressure water filter units. Air compressors are found in treatment plants that use pneumatic actuators to open and close valves and sluice gates for automated process control. Pneumatic actuation is considerably cheaper than electric actuation, however, it often leads to problems due to corrosion caused by condensed air. To avoid this it is necessary to install an expensive water trap and/or air dryer.

There are many different principles on which compressors can operate. The most commonly used for high pressure applications is the reciprocating compressor, which has pistons driven by a crankshaft. Compressors can be either stationary or portable, single or multi-staged and can be driven by electric motors or internal combustion engines. Small reciprocating compressors with power ratings between 1 kW and 25 kW are typically for intermittent duty. Larger reciprocating compressors over 750 kW are commonly found in large industrial and petroleum applications. Discharge pressures can range from low pressure (300 kPa) to very high pressure (40 MPa). In certain applications such as air compression, multi-stage double-acting compressors are most efficient, but are typically larger, noisier, and more costly than comparable rotary units.

Compressor capacity is usually expressed in CFM (cubic foot per minute) and pressure is expressed in psi (pounds per square inch), which is the American equivalent of kPa (kilopascal). 15 psi is roughly equivalent to 10 kPa. The capacity of a compressor (CFM) is what does the work, while the pressure (psi) determines the rate at which the work is done.



Example of a typical compressor, mounted on top of its receiver tank.

learn more about

How the compressor works

The main components of a typical reciprocating compressor system can be seen in the figure on the next page.

The compression cylinders or stages, of which a particular design may have from one to six or more, provide confinement for the process during air compression. A piston is driven in a reciprocating action to compress the air. The pressure is sealed, and wear of expensive components is minimised through the use of disposable piston rings. These are formed from comparatively soft metals relative to piston and cylinder/liner metallurgy, or materials such as polytetrafluoroethylene (PTFE).

Most equipment designs incorporate force-feed lubrication systems. However, when there is zero process tolerance for oil carryover, non-lubricated designs are employed. Some smaller home and shop compressors are typically air-cooled. Large application cylinders are generally fitted with replaceable liners that are press-fitted into the bore, and may include an anti-rotation pin.

Process air is drawn into the cylinder, squeezed, contained and then released by mechanical valves that typically operate automatically by differential pressures.

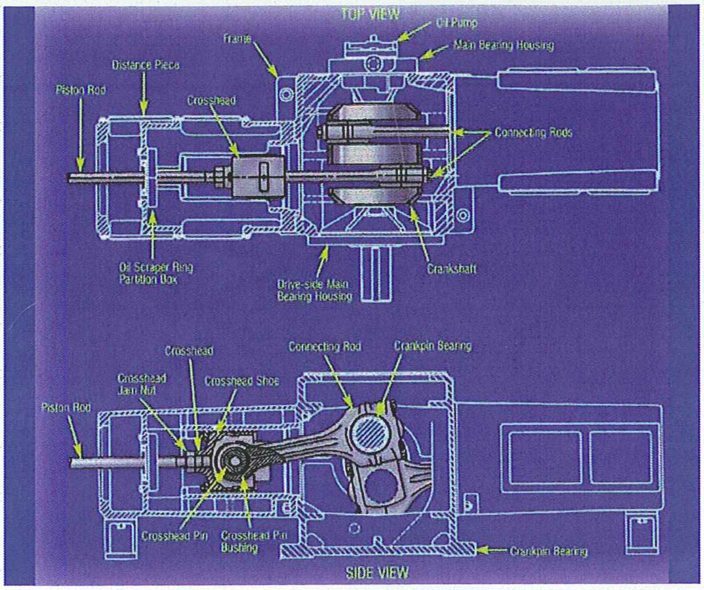
Packing rings contain air pressure within the cylinder, and they keep oil from entering the cylinder by wiping oil from the piston rod as it moves. The packing rings are designed to contain the air within the cylinder, but with the high pressure it is possible that some of the compressed air will leak past the packing rings.

The running gear, housed within the compressor frame, consists of the crosshead and connecting rod which connect the piston rod to the crankshaft, converting its rotary motion into a reciprocating linear motion. The crankshaft is fitted with counterweights to balance dynamic forces created by the movement of the heavy pistons. It is supported within the frame of the compressor by plain bearings at several points. A flywheel is also provided to enhance rotational momentum.

Some compressors lubricate their frame running gear with an integral, shaft-driven oil pump, while others have more extensive, skid-mounted lubrication systems. All properly designed systems provide not only for oil circulation to the critical surfaces of the equipment, but also for lubricant temperature control, filtration and some measure of redundancy.

Suction air is generally passed through suction strainers and separators to remove entrained particles, moisture and liquid phase process fluid that could cause severe damage to the compressor valves and other critical components, and even threaten cylinder integrity, with disastrous consequences.

Typically, reciprocating compressors are relatively low-speed devices, and are direct- or belt-driven by an electric motor. Often the motor is manufactured to be integral to the compressor, with the motor shaft and compressor crankshaft combined, eliminating the need for a coupling.



Cross sections through a typical compressor

Basic compressor maintenance

The following critical maintenance should be done at least once a week to ensure continued operation of a compressor

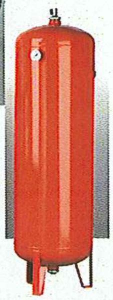
- ☑ Check compressor lubrication level and top up, if required
- ☑ Check condition of air filter and blow out dust with compressed air from the inside of the filter to the outside, but preferably replace any clogged filter
- ☑ If equipped with grease nipples, bearings should be greased once a week
- ☑ Check alignment of V-belt drive and correct, if misalignment is evident
- ☑ Check drive motor for undue temperature and vibration
- ☑ Grease drive motor bearings, if fitted with nipples
- ☑ Check baseplate mounting bolts and tighten – compressors vibrate, which can cause bolts to loosen
- ☑ Wipe down the blower enclosure with a damp rag to remove dust and dirt.
- ☑ Operate blow-down valve to eject moisture from air receiver.

Air receivers or pressure vessels

On the discharge side, compressors are usually equipped with an air receiver, which is essentially a steel tank of sufficient strength to accept the pressurised air or gas. These vessels typically store the compressed gas or air, serve as a pulsation damper and equalise the flow and pressure pulsations caused by the piston's compression strokes.

When air is compressed, it cools down. As a rule of thumb, for every 20°C that the temperature drops, half the water vapour in the air turns into liquid. This liquid or water accumulates in the receiver and needs to be released to prevent corrosion of the tank. This is mostly done by a manual or automatic blow-down valve located at the lowest point of the receiver. By activating this valve, the compressed air forces the water out of the tank into the atmosphere. On large installations this is typically done with an actuated valve controlled by a timer. When done manually, it should be done at least weekly.

In terms of Government Notice R1591, in Government Gazette 17468 of 4 October 1996 and amended by: Government Notice R1 of 8 January 1999 of the Occupational Health and Safety Act, 1993, all pressure vessels and safety valves which have a pressure rating above 40 bar and are subject to possible internal corrosion must be inspected internally and externally and pressure tested by a competent and government accredited person at least once every 3 years.



Horizontal air receiver below the compressor ***(top)*****, and a vertical air receiver** ***(right)*****. Note the drain valve at the bottom of the horizontal air receiver.**

Records should be kept of these inspections in terms of dates, the name of the person who conducted the inspection, the results of the test and any comments.

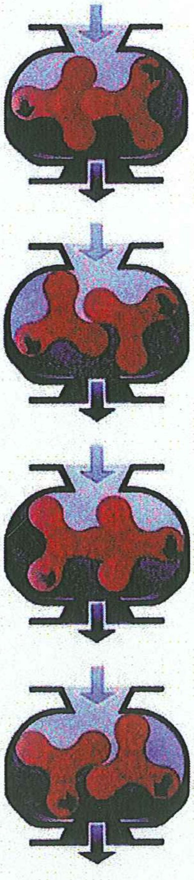
Pressure vessels should be very carefully maintained, as neglect could endanger users. Meticulous maintenance records must thus be kept, recording all activities such as corrosion treatments, etc.

Air blowers

Most blowers used in the water industry are of the 'Roots' type. This type of blower is a positive displacement pump which operates by pulling air through a pair of meshing lobes, not unlike a set of stretched gears. Air is trapped in pockets surrounding the lobes and carried from the intake side to the exhaust. An air blower is usually driven by an electric motor through two pulleys and a V-belt to enable the blower speed to be adjusted by changing the pulley ratios. Changing the rotation speed of the blower has an effect on both its delivery pressure and the volume of air discharged. This principle of operation is what limits the possible pressure differential on blowers. When air or gas is compressed, heat is generated. If the lobes on a blower heat up, they tend to expand, making the clearance between the lobes smaller and smaller. Excessive expansion will cause them to jam, destroying the machine.

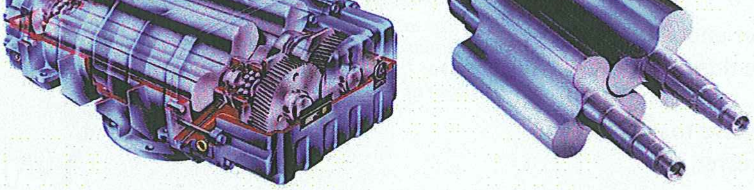
Air blowers are equipped with air inlet filters to ensure that no dust enters the machine, which will cause increased wear. Air blowers are also noisy machines and it is often specified that they have silencing equipment, or are installed in noise-damping cabinets.

The air blower at Keimoes water treatment plant is installed inside a soundproof cabinet.



Cross section showing the operation of the two meshing lobes of an air blower. The lobes trap air from the intake side in the 'side pockets' and push it to exhaust side of the blower.

Cut-away diagram of an air blower with its two meshing lobes, also shown on the right.



Basic air blower maintenance

The following critical maintenance should be done at least once a week to ensure continued reliable operation of a blower

- ☑ Check blower lubrication level and top up, if required.
- ☑ Check condition of air filter and replace whenever necessary, but at least every six months
- ☑ If equipped with grease nipples, bearings should be greased once a week.
- ☑ Check alignment of V-belt drive and correct, if misalignment is evident
- ☑ Check drive motor for undue temperature and vibration
- ☑ Grease drive motor bearings, if fitted with nipples
- ☑ Check base plate mounting bolts and tighten (blowers vibrate, which can loosen bolts)
- ☑ Wipe down the blower enclosure with a damp rag to remove dust and dirt.

Record keeping and reporting

The basis of maintenance management for any facility with electrical and mechanical components is effective record keeping that shows performance and failure trends. It is thus essential to maintain good records of all operation and maintenance activities at pump stations.

This requires that a logbook be kept at every pump station. Every time maintenance personnel visit a pump station, the logbook should be filled in, whether any work was done or not. The logbook should reflect

- all routine inspections
- all mechanical repairs
- all electrical repairs
- all electrical or mechanical failures, and the resulting remedial measures.

It is also important to compile and report costs associated with the maintenance and repairs shown in the logbook. Either as a periodic, separate report or using a job card. *(See example on the following page).*

These records should be summarised **MONTHLY** and reported to management. In addition, such records become an excellent tool for budgeting. If a specific pump is failing regularly, this indicates that it should be replaced, as it is either not the correct pump for the application or it has reached the end of its economic life.

The rule of thumb is that repairs exceeding 60 % of the cost of a new pump should not be done – rather replace it.

Once a record of expenditure and reliability has been established, it is easy to budget, as the cost of running and maintaining a pump station for a year is known.

Excessive repairs also indicate that something is wrong, and the root cause of the problem should be determined. Perhaps insufficient maintenance is being done on the intake works, and large amounts of grit or sand are being deposited in the suction sump, leading to excessive wear on impellors. It is possible to identify these problems when proper repair records are kept.

Checklists and tools for maintenance

The technical manager must ensure that O&M of pumps, drives and pump stations is done correctly in accordance with standards and guidelines provided by O&M handbooks and the manufacturers' manuals for the specific plant and equipment. A maintenance checklist is a simple management tool that can be drafted on the given standards. A checklist gives structure to work processes and it helps operators and other staff to remember what must be done. The checklist can also be used as a control and assessment instrument in a performance management system. And it is always good management practice to document what goes on at work.

There are basically four forms that need to be used for the O&M of pump stations. *See the illustrated examples on next page:* (1) the Maintenance Log, (2) the Weekly Maintenance Checklist, (3) the Monthly Maintenance Checklist. Information from these three, combined with water flow meter and electrical meter readings, are summarised in the fourth

Filled-in examples of a typical pump station maintenance log *(top)*, **a monthly report** *(below right)* **and two maintenance checklists – weekly and monthly** *(bottom left)*.

PUMP STATION MAINTENANCE LOG

Municipality: Perfectly Maintained Municipality

Pump Station Name: Lillyvlei Lifting Pump Station

Location: Lillyvlei Reservoir Complex

Year: 2008

Maintenance and Repair Log:

Date of Visit	Date Pump Removed	Nature of Fault / Comments	Service / Repair	Recommissioning date	Signature
04/08/08		Routine visit by Electrician	Check Earth leakage and protection systems - OK		
11/08/08		Routine visit by Pump Fitter			
18/08/08		Call out: Electricians			
	18/08/08	No. 1 pump motor bearing failure.			

WATER PUMP STATIONS
MONTHLY REPORT

Date: 2008-08-23

Personnel: Operators: 4
Supervisor: 1
Workers: 1

FLOWMETER READINGS:

Pump Station No.1	79 194 kl
Pump Station No.2	107 832 kl
Pump Station No.3	111 417 kl
Pump Station No.4	128 143 kl
Total Monthly Flow:	1 107 103 kl

Average Daily Flow:

5 l/s
24 l/s
32 l/s
18 l/s

...e - inspections only
...ace gland packings
...ce motor / bearings
...e - inspection only

Cost of Replacement Parts
Nil
R364-85
R846-12
Nil

Cost of Replacement Parts
Nil
R10-98
Nil
R332-58

90 734 kWh
241 KVA

... as per schedule.

...dor.

PERFECTLY MAINTAINED MUNICIPALITY

MAINTENANCE CHECKLIST FOR — WATER PUMPSTATIONS

WEEKLY SCHEDULE FOR WEEK 33 TO WEEK 34

PUMPSTATION NAME/NO: Flame Ridge Pump Station OPERATOR/ARTISAN P. Jantjies

	CHECKED YES	CHECKED NO	REMARKS
1 SUBMERSIBLE PUMPS			
1.1 Check for blockages and items snagged on impellor and remove		✓	
1.2 Start the pump and check full load current	✓		Full load current: 3.5 Amps
1.3 Check pressure gauge readings	✓		Delivery pressure: 150
1.4 Lift pump and check operation of quick coupling			
1.5 Remove pump and clean off deposits with high pressu...			
2 CENTRIFUGAL PU...			
2.1 Check oil levels of th...			
2.2 Check condition of th...			
2.3 Check tightness of ba...			
2.4 Check pump for abno...			
2.5 Check pump for abno...			
2.6 Listen for any abnorm...			
2.7 Start the pump and ch...			
2.8 Check pressure gaug...			
2.9 Check the alignment o...			
2.10 Check the condition o...			
2.11 Check operation of the...			
2.12 Check operation of the...			
3 ELECTRICAL SWITCH...			
3.1 Check operation of star...			
3.2 Check operation of ove...			
3.3 Check operation of ove...			
3.4 Start the pump and che...			
3.5 Check proper operation...			
3.6 Check operation of over...			
3.7 Check operation of sump...			
3.8 Check operation of telem...			
3.9 Check condition of electr...			

OPERATOR/ARTISAN O...

SIGNATURE:

PERFECTLY MAINTAINED MUNICIPALITY

MAINTENANCE CHECKLIST FOR — WATER PUMPSTATIONS

MONTHLY SCHEDULE FOR: August 2008 OPERATOR/ARTISAN P. Jantjies

PUMPSTATION NAME/NO: Flame Ridge P.S

	CHECKED YES	CHECKED NO	REMARKS
1 SUBMERSIBLE PUMPS			
1.1 Check for blockages and items snagged on impellor and remove	Not Applicable		
1.2 Start the pump and check full load current			~~Full load current:~~ Amps
1.3 Check pressure gauge readings			Delivery pressure: kPa
1.4 Lift pump and check operation of quick coupling			
1.5 Remove pump and clean off deposits with high pressure water jet (6 monthly)			
1.6 Check oil levels and condition of oil. Replace if milky in colour			
2 CENTRIFUGAL PUMPS			
2.1 Check oil levels of the pump	✓		
2.2 Check condition of the gland packing and replace if required	✓		
2.3 Check tightness of base plate mounting bolts	✓		
2.4 Check pump for abnormal vibration	✓		
2.5 Check pump for abnormal temperature	✓		
2.6 Listen for any abnormal noises	✓		Full load current: 32 Amps
2.7 Start the pump and check full load current	✓		Delivery pressure: 450 kPa
2.8 Check pressure gauge readings	✓		
2.9 Check the alignment on the motor shaft-pump shaft coupling (monthly)	✓		
2.10 Check the condition of the coupling and coupling guard	✓		
2.11 Check operation of the non-return valve	✓		
2.12 Check operation of the motor cooling fan	✓		
2.13 Grease all pump bearings	✓		
3 ELECTRICAL SWITCHGEAR			
3.1 Check operation of starters, contactors	✓		OK
3.2 Check operation of over/under voltage protection mechanism	✓		OK
3.3 Check operation of overload mechanism and circuit breakers	✓		OK
3.4 Start the pump and check operation of ammeters and voltmeters	✓		OK
3.5 Check proper operation of all panel lamps	✓		Replace globe on Trip Indicator
3.6 Check operation of overhead lighting		✓	
3.7 Check operation of sump level control system		✓	
3.8 Check operation of telemetry system (if fitted)			
3.9 Check condition of electrical motor bearings	✓		
3.10 Wash down all switchgear enclosures with a wet cloth	✓		
3.11 Blow out all dust and insects from inside of panel with blower		✓	
3.12 Remove and clean all contactors using a suitable solvent		✓	
3.13 Tighten all cable glands	✓		
3.14 Check that all cables in racks and conduits are secure	✓		
3.15 Check all terminations for integrity and corrosion	✓		
3.16 Check ultrasonic level sensor settings and clean sensor face	✓		
3.17 Check and tighten all electric motor terminals	✓		
3.18 Grease all motor bearings	✓		
3.19 Check all earthing systems and lightning arrestors for correct operation			

OPERATOR/ARTISAN ON DUTY: P. Jantjies (PRINT NAME)

SIGNATURE: Pjantjies

document, the Monthly Report. You will find blank forms of the illustrated examples under *Appendices*, at the back of the ring binder.

The illustrations show examples of two pump station maintenance checklists, one weekly and one monthly. Use them as a model for designing your own checklist for the plant and equipment in your municipality. Add items such as compressors and air receivers, air blowers and transformers, if necessary.

Pump database

It is essential to have a database on all pumps in a municipality. This can be a paper-based system in a lever arch file, or computerised, using spreadsheets or other database software. *See Management Handbook, Booklet 2 on Asset Management.* It should contain all information on the pumps, and be used to maintain and manage these assets. The simple system illustrated in the table below will ensure that the technical manager always has all relevant information on the pumps at his or her fingertips. Every pump should be recorded. This database can be expanded to record repairs and costs incurred, becoming an invaluable tool for a technical manager to keep track of pump maintenance and to budget accurately for maintenance.

The costs of O&M

One way of estimating the cost of O&M of pumps, drives and pumping stations, performed to a professional standard, is to use a percentage of the capital costs, i.e. how much it costs to design and construct the infrastructure and its installation. Sound engineering practice assumes the following figures for the annual maintenance (including both preventative maintenance and repairs)

- Civil/building installations – 2 % of capital cost
- Mechanical/electrical installations – between 1 and 4 % of capital cost, depending on the properties of the pumped water
- Pipelines and associated fixtures – 0,5 % of capital cost.

DATEBASE FOR PUMPS

NO.	PUMP FUNCTION	LOCATION	NO. OF PUMPS	MANUFACTURER AND MODEL	MOTOR INFORMATION	STATIC HEAD (in meter)	DELI
1	Raw water pump	Raw water Pump Station	3	ABS immersible pumpsets	200kW 4 pole ABS 3phase motors	25m	
2	Raw water pump	Raw water Pump Station					
3	Raw water pump	Raw water Pump Station					
4	Dewatering pump	Raw water Pump Station	1	ABS submersible pump	1.2kW 4 pole ABS 3 phase motor	7.5m	
5	Dosing Pump	Chemical Dosing building at water treatment plant	7	Watson Marlow Peristaltic pumps	150W variable speed asynchronous	30m	
6	Dosing Pump						
7	Dosing Pump						
8	Dosing Pump						
9	Dosing Pump						
10	Dosing Pump						
11	Dosing Pump						
12	Clear Water pump	Clear water pump station at water treatment plant	4	KSB 50-250 Centrifugal pumps	200kW 4 pole Siemens 3 phase	70m	
13	Clear Water pump						
14	Clear Water pump						
15	Clear Water pump						
16	Backwash pump	Clear water pump station at water treatment plant	2	KSB 25-40 Centrifugal pumps	30kW 4 pole Alsthom 3 phase	12m	
17	Backwash pump						
18	Irrigation pump	Irrigation pump station : Orange River bank	3	KSB 100-250D Centrifugal pumps	90kW 2 pole Hawker Sidderly 3 ph	98m	
19	Irrigation pump						
20	Irrigation pump						
21	Booster pump	8 SAI Military base pump station	1	Spilhaus N100 Centrifugal pump	30kW 4 pole Alsthom 3 phase	30m	
22	Booster pump	Airport Booster pump station	1	Salweir VEG 100 Centrifugal Pump	45kW 4 pole GEC 3-phase		
26	Booster pump	Experimental Farm booster pump station	2	M&B Multiflo HMA8 Multistage Centrifuga	18kW 2 pole ZEST 3-phase	185m	
27	High lift pump	Keidebees Reservoir Complex	2	KSB 40-250 Centrifugal Pumps	45kW Alsthom 4 pole 3-phase		
28	High lift pump						
29	High lift pump	Paballelo Water Tower pump station	2	KSB 40-250 Centrifugal pumps	15kW 4 pole Siemens 3-phase	20m	
30	High lift pump						

Example of a pump database

It is further assumed that mechanical and electrical equipment will need replacement at 20 year intervals, given adherence to professional O&M standards. However, experience has shown this figure to be very optimistic.

The annual operating costs must be based on hard facts such as actual staff and transport costs and the need for consumables like electricity, fuel and oil, etc.

One could argue that percentage based budgeting is too rough. A newly built pump station should have no serious defects and should require very little maintenance compared to an old one. The use of percentage based budgeting would lead to over-budgeting for maintenance at the beginning of the infrastructure life cycle and under-budgeting towards the end of its lifespan. This is an accepted fact, but practice has shown that over a longer period of time the maintenance costs tend to average within the range given by the percentage. Percentage based estimates are an easy and quick, though admittedly rough method, and adjustments can always be made, based on the age of the pump station.

The general rule of thumb for new pumping equipment is to budget an amount which equals up to 4% percent of the initial pump station capital cost for annual maintenance. Again, this is a departure point for a new pump station. After one or two years of record keeping, the expenditure trend for each installation should be used for budgeting, as a new pump station should have minimum maintenance requirements during its first year of operation. Pump stations pumping raw water and water with a high silt content with abrasive qualities will have a higher maintenance cost of up to 4% of the original construction cost. When pumps are selected for such an application, it is often worthwhile to specify materials of higher resistance, as this may be a cheaper solution in the long-term than replacing impellors annually. This is also true for pump stations driven by petrol or diesel engines, where the drive components may need much higher maintenance inputs.

Zero-based budgeting

Technical managers should use so-called zero-based budgeting based on recorded information, taking into account local accurate knowledge of the condition of the infrastructure and the current costs of repairs and spare parts. Then use the percentage based figures as a comparison to show that the O&M budget is realistic and necessary.

For more information on budgeting, see the Management of O&M Handbook, Booklet 9 – Financial Management.

Health and Safety

Operating and maintaining moving machinery such as motorised pumps is dangerous, and can result in serious injury, if the following correct safety procedures are not strictly followed at all times

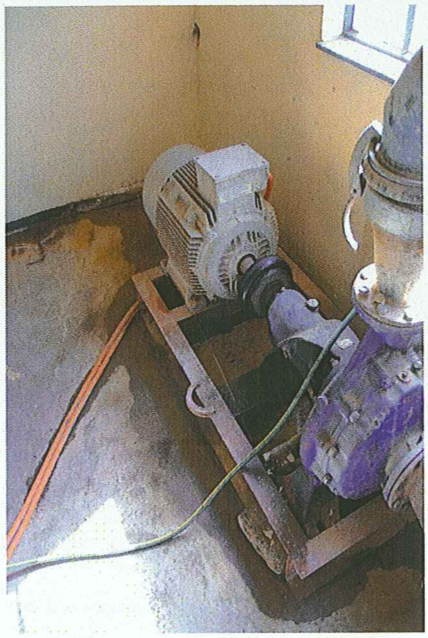
- Avoid wearing loose clothing that could get caught in belts or couplings.
- If the belts are driven by an electric motor, always make sure that they have the necessary belt guards or covers to prevent injury to people.
- With electrical systems there are additional safety precautions to be taken, to avoid electric shocks. Always ensure that the mains circuit breaker is switched off before opening a switchgear cabinet to work inside.
- Never touch any electrical component unless authorised to do so, and follow the correct safety procedures.
- Immediately clear standing water out of the pump house and ensure that water cannot enter the pump house.
- Always wear the necessary ear protection, if it is specified (large pump stations or diesel-driven pump stations).
- Always make sure that all pump sets are completely switched off (switched away from Auto operation, and the Emergency Stop switch activated), and all electrical power is cut before any work is started on a pump unit.

Also see page 54 for chlorination safety measures.

Employers and employees must comply with the Occupational Health and Safety Act at all times.

Read more about health and safety in booklets 2, 3, 7 and 8, and in booklets 4 and 5 of the Management of O&M Handbook.

A sufficient number of fire extinguishers should be mounted in clearly marked, visible places at pump stations and electrical installations. Extinguishers must be part of the maintenance plan and should be checked annually.



Unsafe pump installations are unfortunately a common sight in many municipalities. It is forbidden by Law to run this pump without a proper coupling guard between the electric motor and the pump. There is a real risk of a person being seriously injured by the rotating axle. Imagine someone stumbling over the electrical cabling and/or the green hose-pipe used for priming the pump. Electrical cables should always be protected in a proper cable rack or a conduit.

Typical safety signs

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Glossary

AC
Alternating current

accumulator
a vessel in which air is trapped and compressed by the liquid

actuator
a mechanism that makes a machine or device operate

alternating current
a source of electrical power which changes constantly in amplitude and regularly changes polarity. The changes are smooth and regular, endlessly repeating in a succession of identical cycles to form a sine wave. In South Africa the frequency of changes is 50 cycles per second or 50 Hz.

ampere (amp for short)
unit of electricity equal to a flow of one coulomb per second

amperage
strength of an electrical current in amperes

anomaly
a deviation from the common rule

asynchronous motor
also known as an induction motor, as no current is supplied to the rotor, but a secondary current is induced onto the rotor

atmospheric pressure
the pressure at any given point in the Earth's atmosphere. In most circumstances atmospheric pressure is closely approximated by the hydrostatic pressure caused by the weight of air above the measurement point. Low pressure areas have less atmospheric mass above their location, whereas high pressure areas have more atmospheric mass above their location. Similarly, as elevation increases there is less overlying atmospheric mass, so that pressure decreases with increasing altitude.

bilges
either of the rounded areas that form the transition between the bottom and the sides on the exterior of the hull of a boat or vessel

cavitate
forming of an empty space in a solid body, or of bubbles in a liquid

capacitor
a device used to store an electrical charge, consisting of one or more pairs of conductors separated by an insulator

centrifugal force
the apparent force, equal and opposite to the centripetal force, drawing a rotating body away from the centre of rotation, caused by the inertia of the rotating body

chloramines
a group of disinfectants which are sulphonamide derivatives containing chlorine bonded to nitrogen

concentric
a reducer with end connections having a common centre

conduit
a pipe, tube or the like, for conveying water or other fluid, or for passing cables or wires through

corrosion
the deterioration of essential properties in a material due to reactions with its surroundings

crawl beam
a steel beam mounted overhead on either supporting columns or on existing roof structure, usually of I-beam or H-beam profile. It has a small wheeled trolley (or 'crawler') that runs on it. The lifting equipment such as an electric hoist or chain block is attached to the crawler to supply vertical movement. The crawl beam is used to lift heavy equipment

such as pumps or motors and move them horizontally out of building onto a vehicle.

DC
direct current

direct current
a source of electricity with a unidirectional flow of electric charge

eccentric
a reduce with end connections not having the same centre, not concentric

elastometric
having the elastic properties of a natural or synthetic polymer, e.g. rubber

elevation
the height to which something is elevated or to which it rises

evaporate
to change from a liquid or solid state into vapor

feeler gauge
a gauge consisting of strips of metal of various specified widths, used for measuring narrow gaps or clearances

flanges
projecting flat rim, collar or rib on an object that serves to strengthen or attach it, or in the case of a wheel, maintain its position on a rail

furling
to roll up and secure (a flag or sail, for example) to something else

gantry
a frame or mount for a travelling crane or hoist consisting of a large arch- or bridge-like frame designed to move along a rail or be static

gradient
rate of inclination or slope

gravitational constant
an empirical physical constant involved in the calculation of the gravitational attraction between objects with mass

head
the vertical distance between two points in water or some other fluid, expressed in meters of head

impellor
a rotor for transmitting motion to a fluid or liquid

kinetic
caused by motion

lubrication
to apply some oily or greasy substance to (a machine, parts of a mechanism, etc.) in order to diminish friction

maintenance
care or upkeep, as of machinery or property

Megger insulation tester
an instrument used to apply several hundred to several thousand volts to cables and or motor windings and shows the insulation resistance value

multimeter
a small, battery-powered instrument for basic electrical testing and troubleshooting. Features include voltage, resistance, and current [under 10 amps] reading settings, and sometimes other measurements.

orifice
an opening or aperture, as of a tube or pipe; a mouth-like opening or hole; mouth; vent.

photovoltaic
capable of producing a voltage when exposed to radiant energy, especially light.

pneumatic
operated by air or by the pressure or exhaustion of air

polymer
a substance with a molecular structure built up chiefly or entirely of similar units bonded together, e.g. many synthetic organic materials used as plastics and resins

reciprocating
moving back and forth alternately

reefing
a part of a sail that is rolled and tied down to reduce the area exposed to the wind

resilient
able to return to the original form or position after being bent, compressed, or stretched

rigid
stiff or unyielding

rotor
the rotating element of an electrical or mechanical device

shim
a washer or thin strip of material used to align parts, make them fit, or reduce wear

'soft foot'
where all points at which a motor or pump is connected to the base on which it is mounted are not equally level and firmly secured

soft starter
a device used with AC electric motors to temporarily reduce the load and torque in the power train of the motor during startup. This reduces the mechanical stress on the motor and shaft, as well as the electrodynamic stresses on the attached power cables and electrical distribution network, thus extending the lifespan of the system.

spindle
a rod or pin serving as an axis that rotates, or on which something rotates

spline
a rectangular key fitted into grooves in the hub and shaft of a wheel, especially one formed integrally with the shaft, which allows movement of the wheel along the shaft

stator
the static or stationary part of a motor, dynamo or turbine or other machine about which or in which a rotor rotates

synchronous (motor)
an AC motor distinguished by a rotor spinning with coils passing magnets at the same rate as the alternating current and resulting magnetic field which drives it

taper-lock
a method of attaching a pulley or bearing to a shaft, consisting of a tapered (of reducing diameter) insert which is drawn over the shaft by means of grub screws, which cause the insert to reduce in diameter.

telemetry
the science and technology of automatic measurement and transmission of data by wire, radio or other means from remote sources.

torsion
the twisting of an object due to an applied torque. In circular sections, the resultant shearing stress is perpendicular to the radius, e.g. the power exerted on a drive shaft

undulating
to have a wavy form or surface

vacuum
an enclosed space from which matter, especially air, has been partially removed so that the matter or gas remaining in the space exerts less pressure than the atmosphere

ventilation
the replacement of stale, noxious or hot air with fresh air by mechanical or natural means

viscosity
the property of a fluid that resists the force tending to cause the fluid to flow

vitreous
like glass in appearance or physical properties

volute (of a pump)
the volute of a centrifugal pump is the spiral shaped casing that receives the fluid being pumped by impellor, slowing down the fluid's rate of flow. A volute is curved funnel that increases in area as it approaches the discharge port. The volute converts kinetic energy into pressure by reducing speed while increasing pressure, helping to balance the hydraulic pressure in the shaft of the pump.

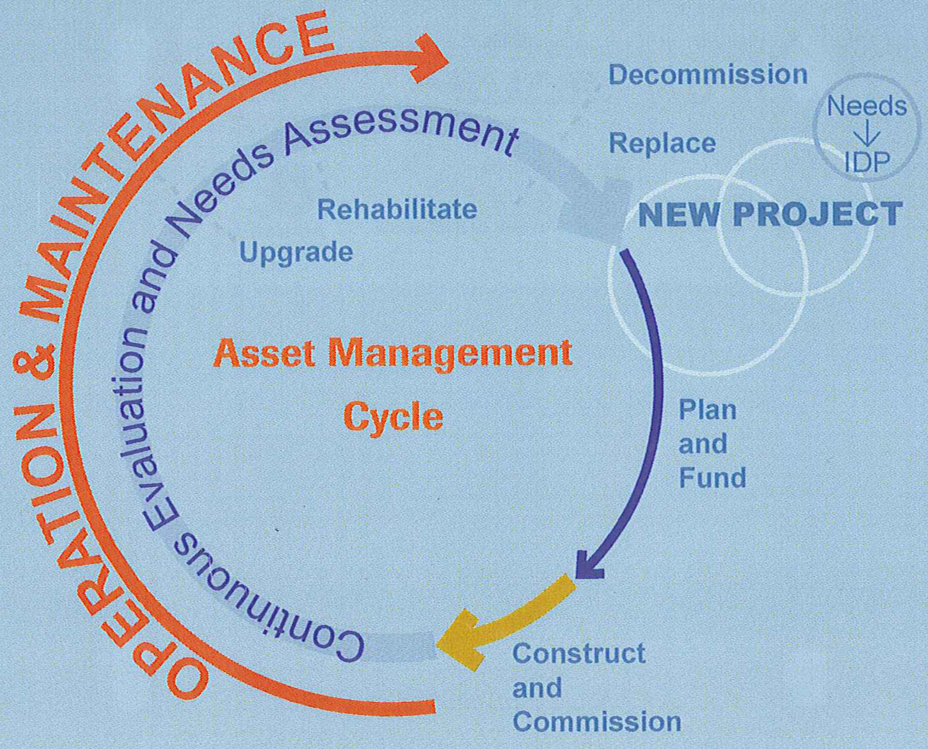
water hammer
the concussion and accompanying noise that result when a volume of water moving in a pipe suddenly stops or loses momentum

Appendices

The following appendices can be found at the back of the ring binder.

Without O&M, assets will be destroyed

Proper O&M is essential if infrastructure is to achieve its planned lifespan. This prevents premature replacement of very costly public assets. For example, a small water treatment plant costs over R3 million. Continuous needs assessments during the O&M phase of the Asset Management Cycle will help determine not only the O&M activities, but also when it is time for upgrading or replacement of infrastructure.



PROJECT PARTNERS

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- SALGA Northern Cape
- Development Bank of Southern Africa
- Swedish International Development Cooperation Agency (Sida)
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