Livestock Watering

FACTSHEET

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PUMPS FOR LIVESTOCK WATERING SYSTEMS

This Factsheet outlines the design and operation of pumps that are suited for livestock watering systems.

Introduction

This Factsheet discusses pump types, characteristics, abilities and limitations. For information on pump suction, lift, and motor horsepower requirements refer to Factsheet #590.304-3, ***Livestock Water System Design #3: Calculating Pumping Requirements***.

Output & Energy

Although the following looks at many types of pumps, all can be characterized by:

- pump output at various heads (lift) and speeds
- energy options to power the pump

Manufacturers will show pump performance as a graph or table giving the volume of water that can be delivered to various heads by operation conditions such as pump speed. Reviewing this information will indicate pump efficiency for the conditions under which it will have to operate. Some pumps operate in a narrow range for best efficiency (such as centrifugal pumps), others will operate in a wide range.

For livestock watering systems without 'grid' electrical energy, the pump selected must be able to be powered by the available energy options. Refer to Factsheet #590.305-1, ***Pumping Livestock Water: It's All About the Energy Choices!***

Principles for Lifting Water

Livestock water can be lifted by one (or combination of) the following principles:

- **direct lift**; physically lifting water in a container
  - not usually used in livestock watering systems
- **displacement** – pushing water (water is 'incompressible') in an enclosed space
  - reciprocating pumps like piston, diaphragm, can be used
  - rotary gear, vane, and mono pumps are less commonly used
- **creating a velocity head** – propelling water to a high speed and using the momentum to create a flow
  - centrifugal and jet pumps can be used
- **buoyancy of a gas** – bubbling air through water to lift a proportion of it
  - air lift system that pumps from a well
- **gravity** – manipulating water flow due to gravity to create 'water hammer'
  - hydraulic ram pump and modified ram pump (Glockemann)

Comparing Pumps for Livestock Watering

There are many types, sizes and drive methods of pumps suitable for livestock watering systems that usually have low daily volume requirements. Whatever the design, pumps can be for surface or ground water; for shallow or deep well applications; submerged or non-submerged. Table 1, next **two pages**, lists pump characteristics for pumps typically used in livestock watering systems.

Table 1 Characteristics of Pumps Typically Used in Livestock Watering Systems

Pump Type	Shown in Figure [1]	Practical Suction Lift [2] m	Practical Suction Lift [2] ft	Output [3] low / med / high	Usual Head m	Usual Head ft
Displacement / Reciprocating						
piston	Figs 1 & 2, pg 4, 5	6.7	22	low / med	to 200	to 650
diaphragm	Fig 3, pg 5	6.7	22	low / med	to 10	to 35
Displacement / Rotary						
progressive cavity	Fig 4, pg 6	usually submerged		low / med	to 100	to 325
coil [4]	Fig 5, pg 7	no suction ability - inlet submerged		low	to 25	to 80
Velocity						
centrifugal	Fig 6, pg 8	4.6	15	med / high	to 45	to 150
turbine-centrifugal	Fig 6, pg 8	usually submerged		low / med	to 275	to 900
jet	Fig 7, pg 9	4.6 - 6 below ejector	15 - 20 below ejector	low / med	to 45	to 150
Air Lift						
air lift	Fig 8, pg 11	no suction ability		low	to 50	to 165
Hydraulic Ram						
hydraulic ram	Fig 9, pg 11	no suction ability –flooded suction by design		low	to 100	to 325
hyd. ram w/ piston [5]	Fig 10, pg 12	suction usually flooded or less than 1m (3 ft) lift		low	to 200	to 650

[1] refer to the following Figures and text for pump details

[2] at sea level; reduce 0.3m / 300m (1 ft / 1000 ft) elevation above sea level; doesn't apply to submersible pumps (flooded suction) for details on suction, refer to Factsheet #590.304-3, ***Livestock Water System Design #3 Calculating Pumping Requirements***

[3] as pump is typically used for a livestock watering system: low = under 5 USgpm; medium = 5-10 USgpm; high = over 10 USgpm

[4] typical coil pump is available as the *Sling Pump*

[5] a modified hydraulic ram (has a diaphragm-driven piston pump) that is available as the *Glockemann Pump*

Table 1 (Continued)		
Abilities [1]	**Limitations** [1]	**Comments** [1]
Displacement / Reciprocating		
-high heads possible	-needs clean water; filter intake	-cylinder version is typical windmill pump -hand operation possible
-will handle most stock water	-head limited	-available as 12/24 V DC motor/pump unit
Displacement / Rotary		
-output proportional to rotational speed	-needs clean water; filter intake -high starting resistance; use high torque motor	-suited to solar-direct power that has variable speed due to sunlight conditions - suited to low volume high head sites
-easy to install, maintain, move -900 USgday to 80ft; 4000 USgday to 25ft	-high drive water relative to output	- *Sling Pump* is powered by stream flow
Velocity		
-handles water with sand and silt -high volume capacity possible	-limited work range; efficiency depends on operation w/design head & speed -smaller sizes (for stock water) have lower efficiency -must be primed; need foot valve	-commonly used pump -very efficient above 50 USgpm and up to 150 ft -pump spiral casing converts water velocity to pressure (*volute pump*)
-diameter allows use down well casing		-typical submersible well pump -stationary diffuser converts water velocity to pressure (*turbine pump*)
-ability to handle air - self priming	-damaged by sand in water -efficiency reduced as head increased	-used where suction a concern
Air Lift		
-very simple system -compressor can be offset from well	-may require a deep (costly) well	-low overall efficiency
Hydraulic Ram		
-drive energy is the supply water	-high drive water relative to output -requires fall in water supply	-complete motor / pump system
-as ram above, but higher head possible from larger volume/lower fall of water supply	-as above	-as above

[1] refer to the following Figures and text for pump details

Pump Suction Limitations

Surface-mounted pumps create a vacuum in the suction line and atmospheric pressure moves water up to the pump inlet (similar to using a straw to drink a liquid). How well a pump functions depends on its ability to create this vacuum. Positive displacement pumps are preferred over centrifugal pumps when suction lift is important.

As suction is due to atmospheric pressure, it has a practical limited of 6.7m (22 ft) maximum at sea level and is reduced with increased elevation above sea level. The efficiency of most pumps will be improved if the suction lift is kept to a minimum. For details on pump suction above sea level, refer to Factsheet #590.304-3, ***Livestock Water System Design #3 Calculating Pumping Requirements***.

For situations where the depth to water is greater than 6.7m (22 ft), the pump must be set closer to the water level, possibly lowered into the water. By doing so, the suction lift is reduced (to zero if submerged and the pump inlet is flooded). These pumps can be either driven by a surface-mounted motor or with a submerged motor.

One exception to this are Jet pumps which are surface mounted but can lift water from greater depths through the use of their intake design (refer to page 9).

Wells/Surface Motor. These pumps use a standard above-ground motor that drives a shaft to power the submerged pump. This allows a wider selection of power units but has the added complication of a driveshaft extending down the well. This restricts the practical depth to water that this combination can be used on.

Wells/Submerged Motor. This design allows for maximum well depths to be pumped with relatively simple systems. Both the electric motor and the pump are submerged. While simple, fully submerged pumps (depending on the depth) may be more expensive than surface-driven pumps due to the cost to waterproof the motor.

Displacement Pumps - Reciprocating

Because water is (for practical purposes) incompressible, any device that acts to push or displace water in a confined area acts as a pump. Reciprocating pumps are positive displacement pumps whose basic internal design is characterized by a cyclic motion (forward/backward or upward/downward). They are often a simple design well suited to low volumes and a wide range of lifts, a good match for livestock watering.

Piston Pump. These pumps are usually a very basic design and could be compared to a hand-operated bicycle air pump. Water is delivered with each cycle. Due to the piston-to-wall contact these pumps are not usually suited to water containing dirt or grit.

Figure 1 (right) illustrates a piston pump installed down a well. The pump rod could be driven by an electric motor or by a windmill.

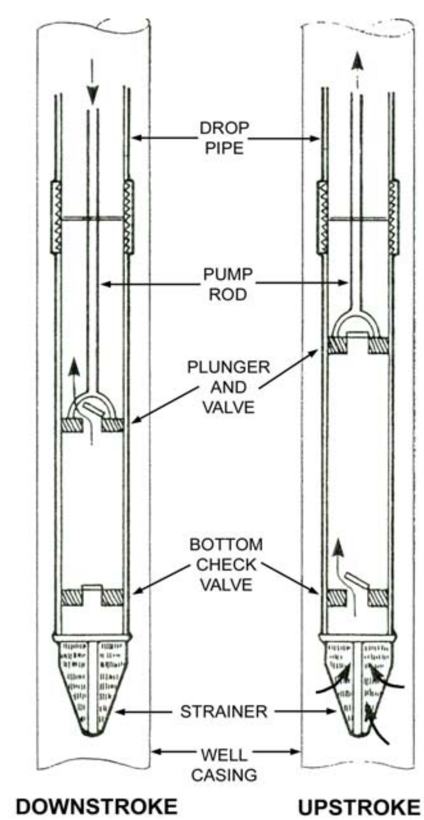


Figure 1 Piston Pump

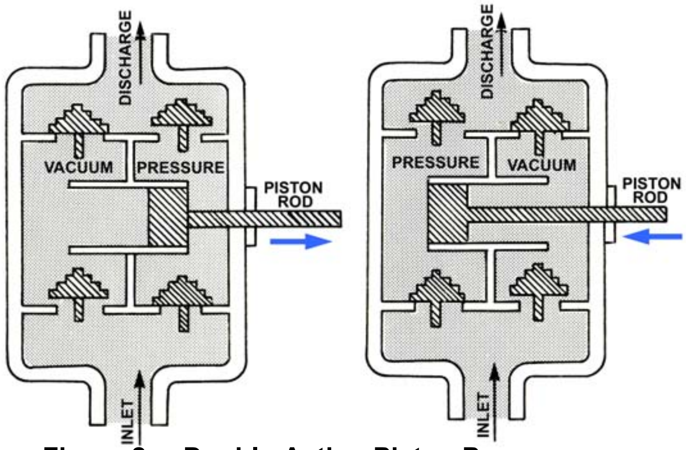


Figure 2 Double-Acting Piston Pump

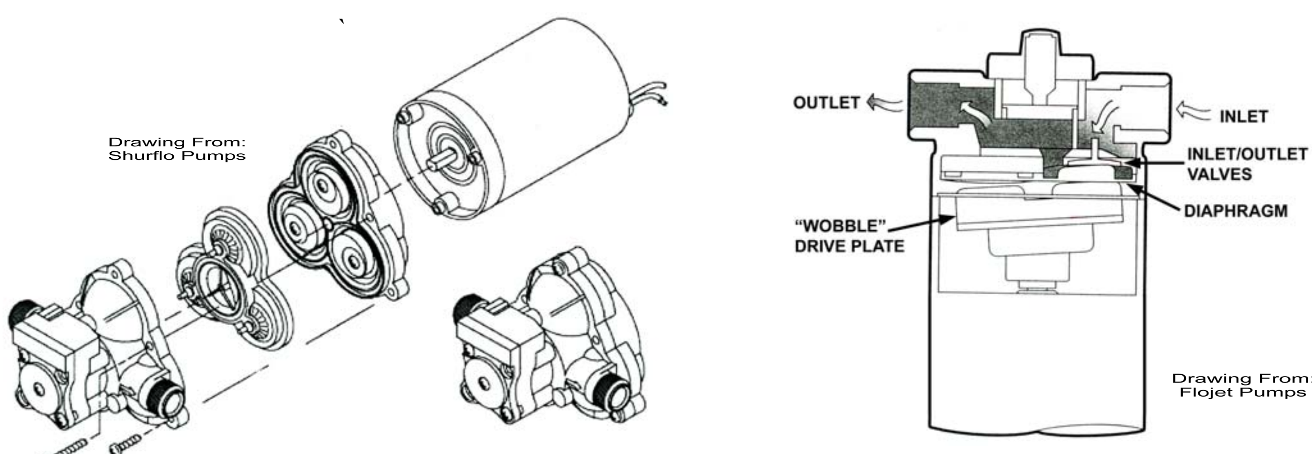
A double action piston pump has two chambers each with suction and discharge valves which are activated by a reciprocating piston. Water is alternatively drawn in and discharged from each chamber. The resulting flow is constant but pulsating which can cause vibration and noise. These pumps can tolerate small amounts of silt or sand in the water. They can be easily installed over small diameter wells or offset from the well.

Deep well piston pumps are capable of lifting water up to 180m (600 ft). These pumps are driven by power transmitted through a gear box which produces a reciprocating vertical motion in a drive rod. This rod is directly connected to the pump located in a cylinder below the pumping water level. A drop pipe connects the pump cylinder to the well head at the ground surface to deliver the pumped water. The pump cylinder may be single or double acting.

Since deep well piston pumps must start against pressure, motors with high starting torque are required. Pump capacity depends on cylinder size and number of strokes per minute. Pressures that can be produced are limited by motor horsepower and pump equipment strength. Deep well piston pump drives are installed directly over the well.

Diaphragm Pump. These pumps are well suited for livestock watering systems. They consist of a flexible diaphragm, usually of synthetic rubber, which is driven to flex back and forth alternately creating suction and delivery strokes. Spring loaded valves control the water flow as shown in Figure 3, below.

These pumps can handle silt and sand in the water. They are generally low cost, low maintenance designs that are self priming and positive displacement. Pumps are available for a variety of heads and capacities. However, they are noisy due to the vibration caused by the pulsating water flow through the pump. They are commonly used in configurations of one to four diaphragms and can be either submersible or surface mounted.



EXPLODED VIEW **CUTAWAY VIEW**

Figure 3 Typical Diaphragm Pump

Displacement Pumps - Rotary

Rotary pumps are positive displacement, usually valveless, simple, compact, light in weight and low cost. Designs include gear, vane and helical rotor pumps. They are characterized by designs which use a shape that goes through repetitive changes as it rotates, allowing water to be drawn in and released. They have a constant discharge per revolution under various heads. Wear as a result of silt or sand in the water is a common problem because of the close tolerances necessary between the rotating and stationary components. They are usually best suited to clean water in low volumes and medium to high lifts up to 75m (250 ft).

Most rotary pump designs are best suited to surface mounting for pumping surface water or shallow well water.

Progressive Cavity Pump. These pumps (also called helical or spiral rotor pumps) consist of a molded rubber stator (stationary part) in which rotates a helical metal rotor. As the rotor turns, water is trapped between the rotor and stator. This water is moved progressively along the rotor as it rotates and is continuously discharged as a uniform flow. Because the cavity formed by the rotor/starter moves progressively as the pump rotates, these pumps are often referred to as progressive cavity pumps. They could be compared to an auger moving grain.

This design can tolerate some silt and sand in the water due to the rubber stator. Due to the internal friction a drive motor with high starting-torque ability is required. As shown in Figure 4, the pump can be directly connected to the motor and surface mounted or submerged, or it can be shaft driven.

A project using solar energy to power a progressive cavity pump (*Mono Pump*) is covered in Factsheet #590.305-6, ***Using Solar Energy to Pump Livestock Water.***

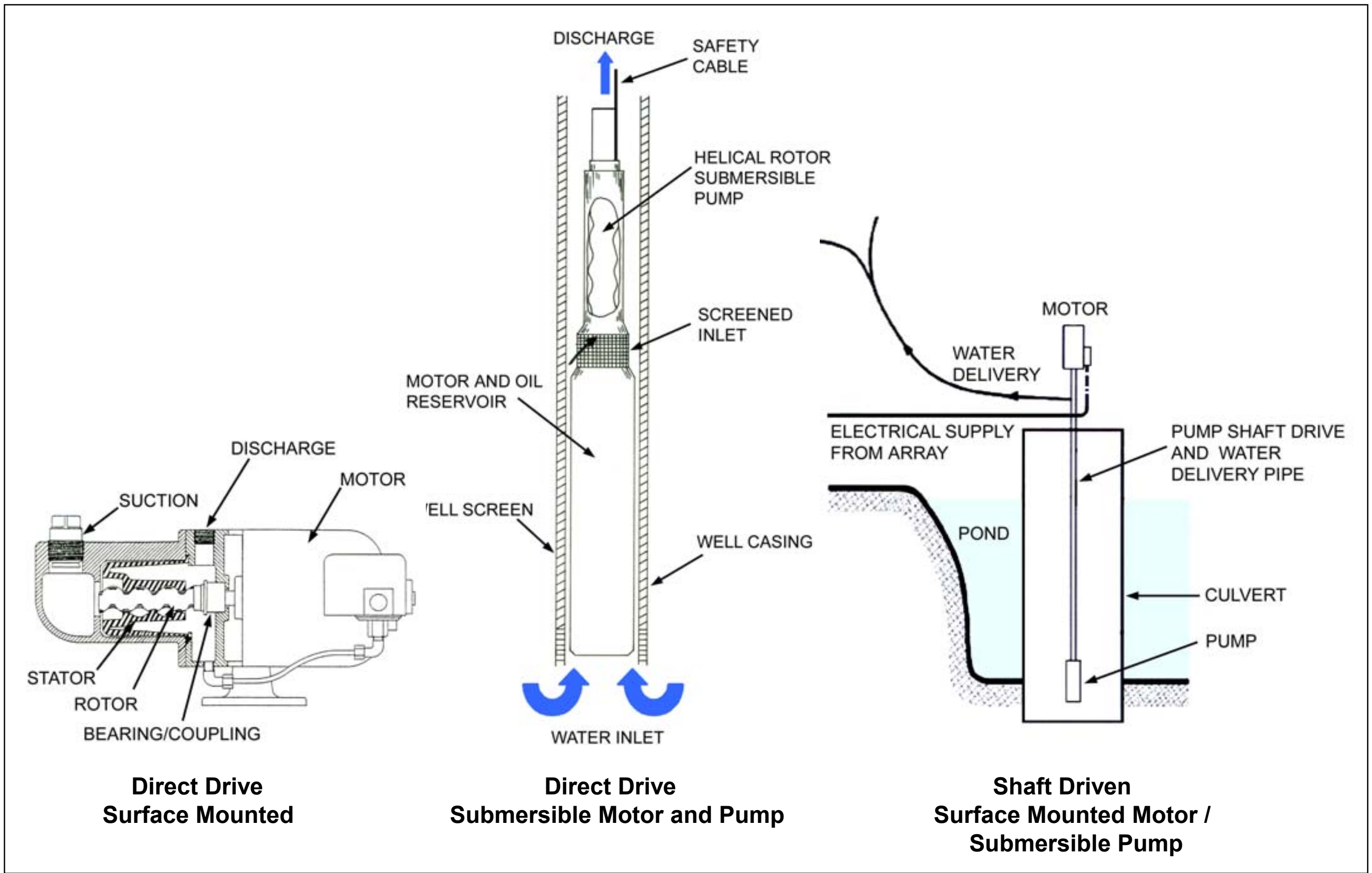


Figure 4 Progressive Cavity Pump Drive Options

Coil Pumps. These pumps are a motor / pump system that use specific gravity water flow conditions to drive the pump (similar to hydraulic ram pumps). A small portion of the drive water is pumped. In the case of a *Sling Pump*, a commercially available coil pump shown in Figure 5, below, the drive water is a flowing stream. The stream at least 400 mm (16 inches) deep and with a 0.6 m/sec (2 ft/sec) flow rate is required. Different pump models offer lifts to 24m (80 ft) and volumes to 15,000 litres (4,000 USgal) per day.

The *Sling Pump* is covered in Factsheet #590.305-8, ***Using Stream Energy to Pump Livestock Water.***

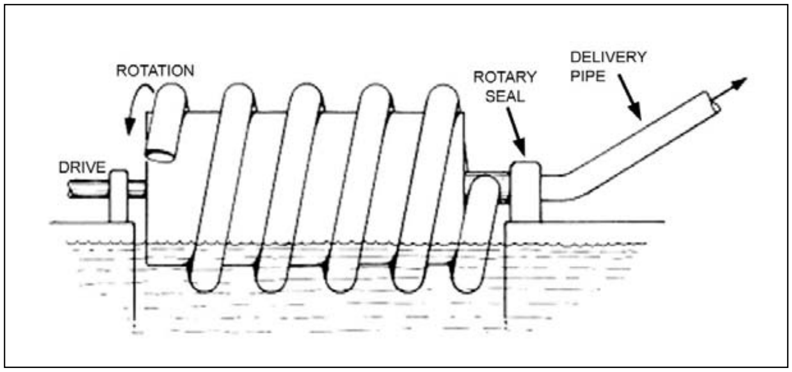


Figure 5 Coil (*Sling*) Pump

Velocity Pump

Centrifugal Pump. These pumps consist of an impellor that rotates within a circular cavity. Water enters the pump through the centre or eye of the impeller, increases in velocity as it moves across the impeller face, and is discharged by the impeller into the diffuser where the water is slowed down, converting some of the velocity into pressure. This is similar to the 'discharge' that occurs when a weight on a string is whirled around and released – it will fly away some distance.

Water is drawn into the centrifugal pump by atmospheric pressure but these pumps must be manually primed. Suction lift (at sea level) is restricted to 4.6m (15 ft), and at 600m (2000 ft) suction lift is 4m (13 ft). These pumps are used when minimal suction lifts are required, such as lakes, ponds, streams etc. A good foot valve is required on the suction line to prevent lost of prime.

A centrifugal pump produces a smooth, uniform flow of water. Open impeller type pumps are capable of pumping water with some sand; however closed impeller (turbine) pumps should be used in clean water conditions. Centrifugal pumps provide good service life and are very reliable.

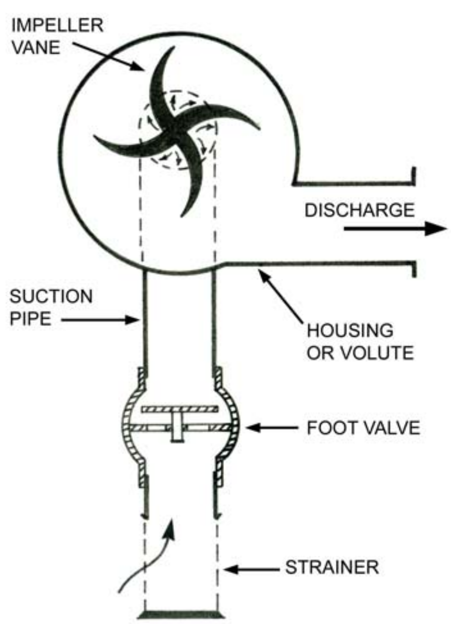
Pump efficiency will depend on the impeller speed, operating head and flow rate delivered. High efficiency is usually only possible for a narrow range of operating conditions so it is very important that pump selection matches site conditions.

Turbine-Centrifugal Pump. These pumps consist of centrifugal impellers mounted on a single shaft and all operating at the same speed. Each impeller passes the water to the eye of the next impeller through a diffuser. Each impeller-diffuser combination is called a stage. Pumps can be single or multistage. The capacity is determined by the width of the impeller and diffuser. The pressure is determined by the impeller diameter, rotation speed and the number of stages. Note that additional stages increase pressure but do not increase flow.

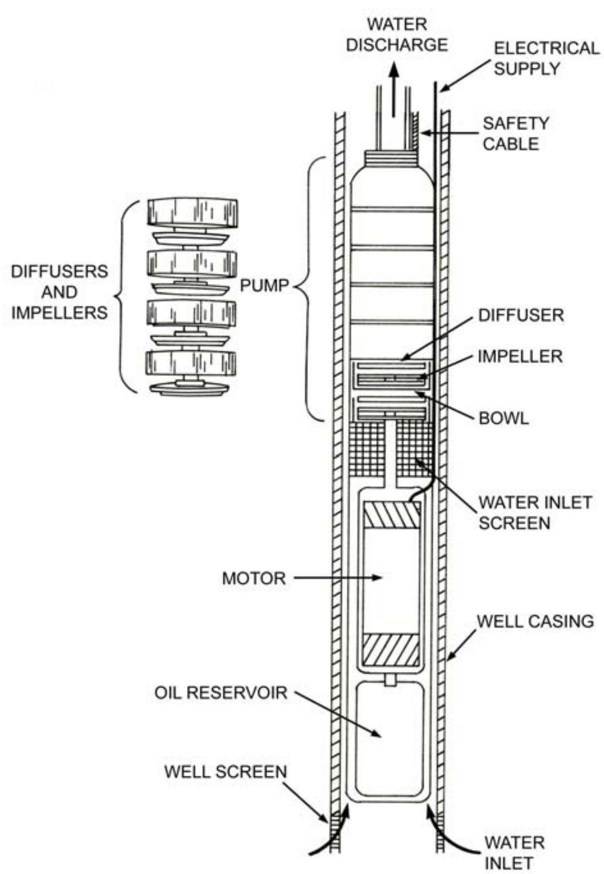
Some restrictions apply when these pumps are used in well situations. Pump output is partly determined by impeller diameter but this is restricted by the diameter of the well casing. If higher pressures are required for higher lifts more stages are used making the pumps longer. If the pump is going in a drilled well, these long pumps require either a very straight well or a larger diameter well.

Deep well centrifugal pumps can be driven by electric motors of two different types: submersible or surface mounted (line shaft driven).

- **Submersible Deep Well Centrifugal Pumps**. These pumps consist of multistage centrifugal impellers driven by specially designed motors that are capable of operating underwater.
- **Vertical Line Shaft Deep Well Submersible Pumps**. These pumps are generally used for high capacity, high head installations where the horsepower requirements exceed the capability of submersible motors. A line shaft turbine pump consists of a surface mounted motor driving the submersible pump. These pumps may not be used for the small pumping requirements of many livestock watering systems.



Typical Centrifugal Pump



Submersible Turbine-Centrifugal Pump

Figure 6 Cutaway of Centrifugal Pumps

Jet Pump. These combine two pumping principles, centrifugal action and venturi injection. These pumps are of simple design, low cost and quiet operation, requiring minimum maintenance.

Jet pumps consist of a pump (usually centrifugal) and a jet or ejector assembly. The centrifugal pump portion functions as described previously with an impeller and diffuser to produce the required output. However, instead of the total discharge going to the delivery pipe, some is returned to the jet to assist suction. This jet is made up of a body, nozzle and venturi tube. The return portion of the pump output water is forced through the nozzle and into the venturi tube. In passing through the nozzle a partial vacuum is created which assists in the pump suction.

The venturi tube, which gradually increases in size, slows the water down converting the velocity into pressure. Drive water and pumped water therefore emerge from the venturi at relatively high pressures. This water once again passes through the centrifugal pump where a portion is returned to the jet and a portion is pumped out the discharge line.

The amount of water returned to the ejector must be increased as the lift increases. For example, 50% of the total water pumped is returned to the jet at a 15m (50 ft) lift, but 75% is returned at 30m (100 ft) lift. Therefore efficiency goes down with increased lift.

The jet pump action has the advantage of pumping limited amounts of air without difficulty, have relatively few moving parts and have a continuous smooth pumping action. They are easily primed. Jet pumps are easily damaged by sandy water. The flow capacity depends on impeller diameter, speed, and pump design.

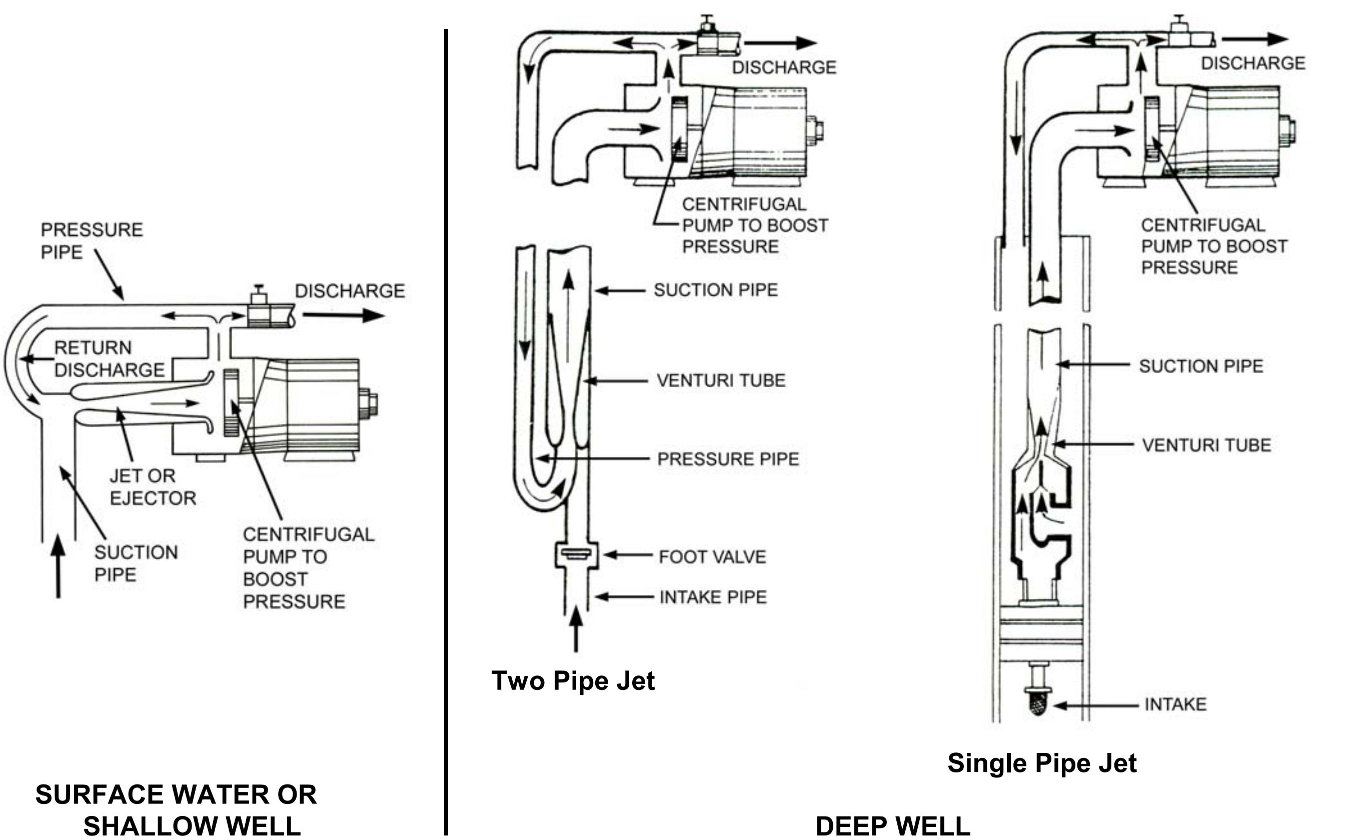


Figure 7 Jet Pump

- **Shallow Well Jet Pump**. These pumps have the ejector mounted in or attached to the surface-mounted pump housing. A suction line attached to the jet extends down below the water level. At start up, the centrifugal impeller forces a stream of water through the ejector creating a vacuum which draws water from the well to the pump. Maximum lift for a shallow well jet pump is 4.5 to 6m (15 to 20 ft).
- **Deep Well Jet Pump**. These pumps have the ejector submerged in the water down the well. They can be equipped with more than one ejector, depending on the well depth, capacity and pressure required. Deep well jets are available in two pipe and single pipe or "packer" systems. In a single pipe system the space between the well casing and the suction pipe serves as the pressure pipe. A well casing adaptor is required to seal the casing to allow it to act as a pipeline.

Air Lift Pump

This pump uses compressed air, delivered to the bottom of a submerged pipe in a well, to lift an air/water mixture to the surface. The pump principle is that an air/water mixture, with as little as half the density of water, will rise to a height above the water level approximately equal to the immersed depth of the pipe. Depending on the lift required, this submersion depth may require a deep well (refer to "Total Length" in Table 2, below). The air line can be placed inside the discharge pipe or, as shown in Fig 8, next page, outside and parallel to it. A 'foot piece' breaks the air into small bubbles that conserves air and improves efficiency. A homemade device can be used consisting of 1/16 inch holes in a copper tube that extends at least 2 feet up into the pipe.

The main advantage of this pump is its simplicity. The disadvantages are the very low overall energy efficiency and the well depth for higher lifts. Submergence in Table 2, below, is "**minimum**" (the least submergence but requires more compressed air per volume of water delivered) or "**best**" (least amount of compressed air per volume of water delivered but deepest well – "total depth" - required).

Table 2 Air Lift Pump Requirements for Livestock Watering Conditions [1]

Pumping Rate		Water Discharge Pipe Size			
		½ inch air line inside water line [1]		½ inch air line outside water line [1]	
litres per min	USgal per min	mm	inch	mm	inch
4 to 15	1 to 4	25	1	13	0.5
15 to 26	4 to 7	32	1.25	19	0.75
26 to 42	7 to 11	38	1.5	25	1

Air Lift Performance for Minimum and Best Submergence [1]

Depth to Pumping Water(lift L)		Depth of Air Line Below Pumping Water (submergence S)				Total Length (lift L + submergence S)				Volume of Air Required per Volume Water Pumped			
m	feet	m		feet		m		ft		m^3/min per m^3		ft^3/min per USgal	
		min	best	min	best	min	best	min	best	min	best	min	best
7.6	25	8.8	16.8	29	55	16.4	24.4	54	80	2.06	1.35	0.28	0.18
15.2	50	15.8	28.4	52	93	31.0	43.6	102	143	3.74	2.24	0.50	0.30
30.5	100	27.1	45.7	89	150	57.6	76.2	189	250	6.58	3.52	0.88	0.47
45.7	150	34.5	55.8	113	183	80.2	101.5	263	333	8.83	4.64	1.18	0.62
60.1	200	42.4	65.9	139	216	102.5	126.0	339	416	10.92	6.21	1.46	0.83

[1] refer to Figure 8, next page

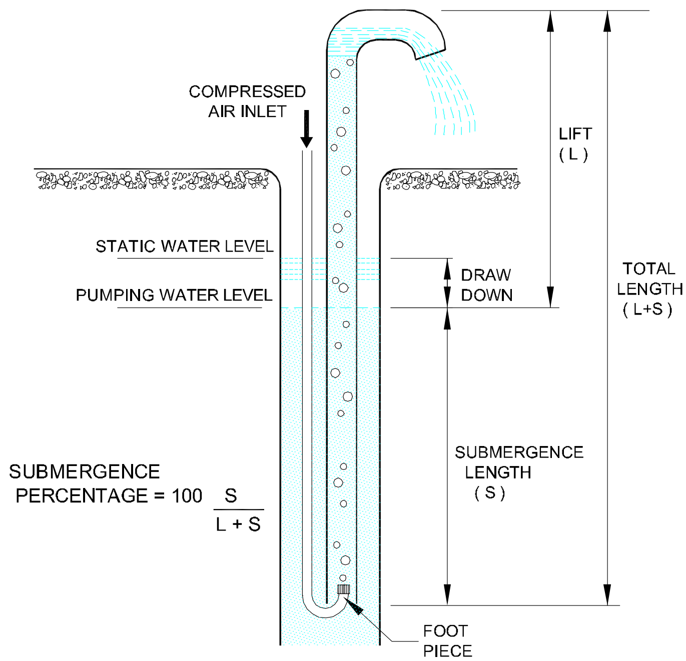


Figure 8 **Air Lift Pump**

Hydraulic Ram Pump

The following two pumps are actually a motor / pump system. Both use specific gravity water flow conditions to drive a pump that pumps a small portion of the drive water. The traditional ram pump is shown in Figure 9, below, and a modified ram pump is shown in Figure 10, next page.

The traditional hydraulic ram pump operation and setup, etc is covered in Factsheet #590.305-9, ***Using A Hydraulic Ram to Pump Livestock Water.***

A modification of the traditional hydraulic ram pump is available as a *Glockemann Pump*. It is covered in Factsheet #590.305-10, ***Using A Modified Hydraulic Ram to Pump Livestock Water***.

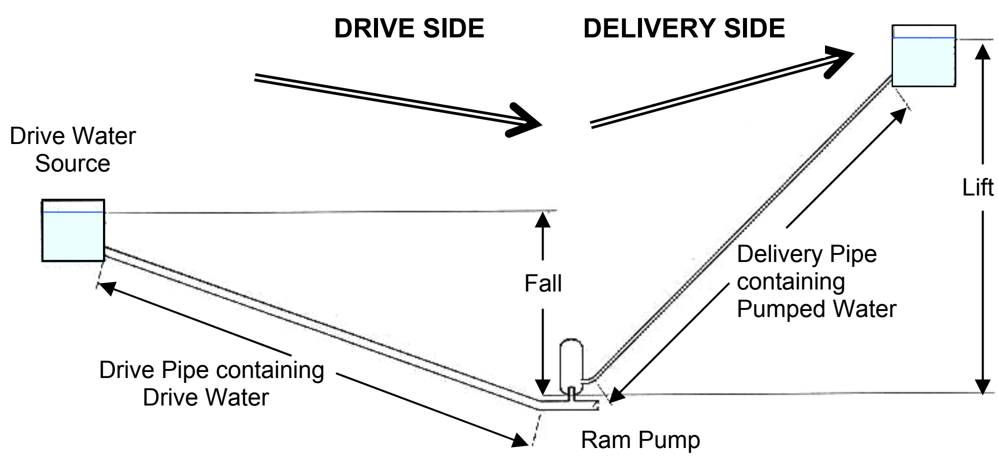


Figure 9 **Hydraulic Ram Pump**

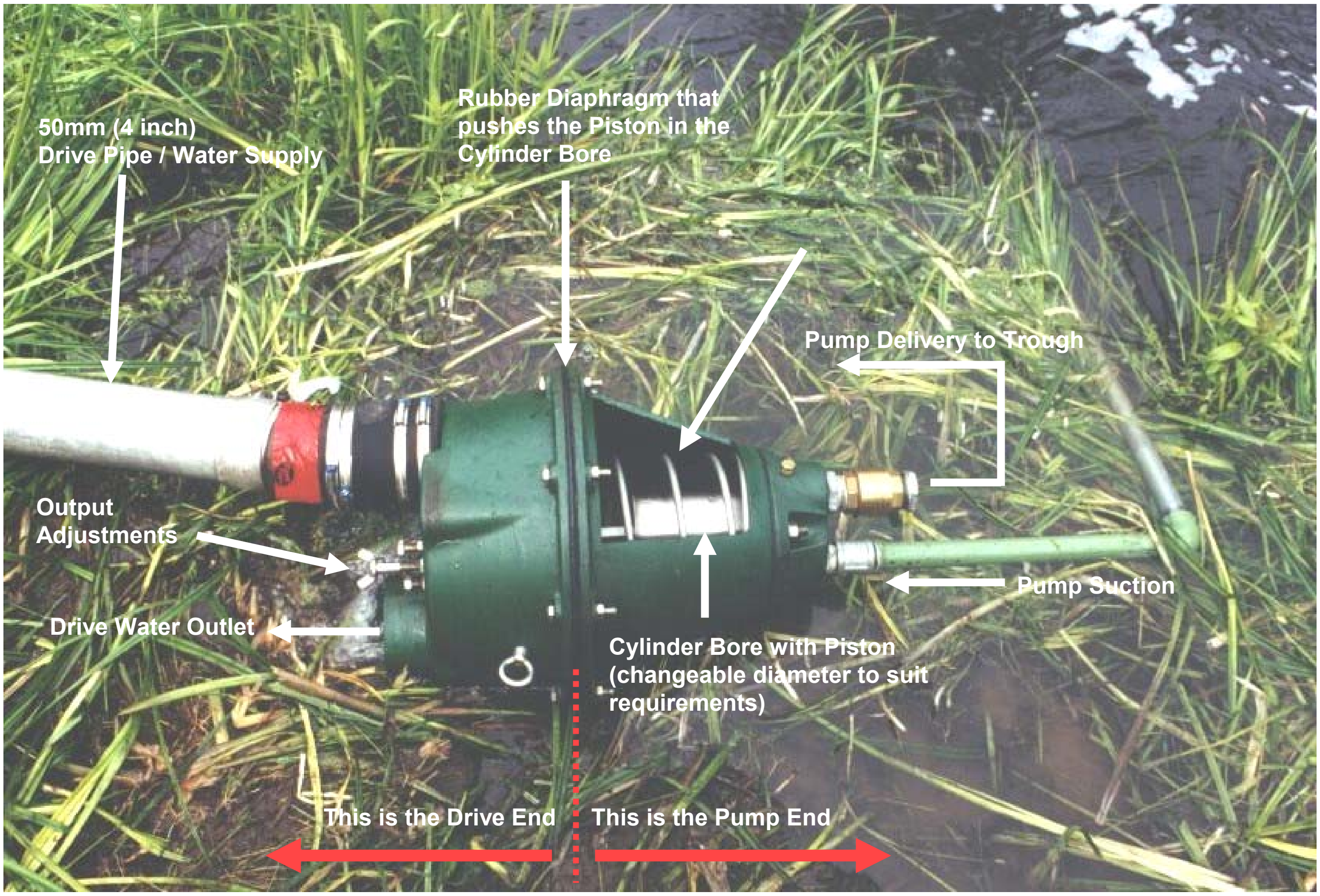


Figure 10 **Modified Hydraulic Ram Pump (*Glockemann 320*)** (delivery line not shown)

More Information

Refer to the following publications for detailed information on pumps.

- *Water-Pumping Devices*
  Peter Fraenkel, Intermediate Technology Publications, 1995
- *Internet Glossary of Pumps* web site has animated diagrams of how pumps work

http://www.animatedsoftware.com/elearning/All%20About%20Pumps/glossary/aap_glossary.swf

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