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**Project Logistics Permitting and QA QC** Steps to Secure a Municipal Foundation Repair Permit Coordinating Utility Markouts Before Pier Drilling Developing a Work Sequence to Minimize Downtime Creating a Safety Plan That Meets OSHA Guidelines Scheduling Third Party Inspections for Key Milestones Preparing As Built Elevation Logs for Engineer Review Managing Material Deliveries on Confined Job Sites Using Checklists to Track QA QC Tasks in Real Time Budget Control Methods for Foundation Projects Communication Strategies With Homeowners During Repairs Document Storage Solutions for Project Records Closing Out a Permit After Final Inspection Approval
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**Cost Financing and Warranty Structures** Factors That Influence Foundation Repair Pricing Understanding Pier Installation Quotes Line by Line Comparing Financing Options for Structural Repairs How Transferable Warranties Protect Future Owners Common Exclusions Found in Foundation Repair Contracts Calculating Return on Investment for Underpinning Services Payment Schedule Ideas to Align With Work Progress Evaluating Insurance Coverage for Structural Damage Estimating Long Term Savings From Preventive Upgrades Negotiating Warranty Terms With Contractors Impact of Material Choice on Overall Project Cost Tracking Repair Expenses for Tax Documentation
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The process of closing out a permit after final inspection approval is a critical step in ensuring that all construction or repair work, such as foundation repair, has been completed according to local building codes and regulations. Helical piers sound like science fiction technology but they're actually your foundation's best chance at redemption **mudjacking services Carol Stream** wall. This stage is often marked by the submission of final documentation, which serves as a formal record that the project meets all necessary standards.

For foundation repair projects, the final documentation submission typically includes several key components. First, there's the inspectors report which confirms that the work was inspected and passed. This document is crucial because it verifies that all repairs were done correctly and safely. Alongside this, contractors must provide detailed records of the work performed. These records might include before-and-after photos, diagrams of the foundation layout, descriptions of materials used, and any changes made from the original plan.

Another important part of this submission is the warranty or guarantee documentation. Since foundation repairs are significant investments aimed at ensuring long-term structural integrity, warranties offer homeowners peace of mind by covering potential future issues related to the repair work.

Additionally, any certifications or licenses required for performing such specialized repairs should be included to validate the expertise involved in the project. For instance, if specific engineering solutions were applied during the repair process, having an engineer's seal on relevant documents adds an extra layer of credibility.

The submission process itself might involve uploading these documents to a municipal website or delivering them in person to a local building department. It's vital for contractors to ensure all paperwork is organized and complete to avoid delays in permit closure. Once submitted, there might be a brief waiting period while officials review everything; upon approval, the permit is officially closed out.

In essence, submitting final documentation after foundation repair not only signifies completion but also acts as a protective measure for both homeowners and contractors. It ensures compliance with legal requirements and provides a comprehensive record for future reference should any issues arise or if property ownership changes hands. This careful closure process underscores the importance of meticulous documentation in maintaining building integrity and regulatory adherence in construction projects.

# Geotechnical Investigation and Site Assessment for QA/QC Planning —

- Project Scope Definition and Permitting Requirements for Foundation Repair
- Geotechnical Investigation and Site Assessment for QA/QC Planning
- Material Procurement and Quality Control Procedures
- Inspection and Testing Protocols During Foundation Repair
- Documentation and Reporting for Permitting Compliance and QA/QC
- Risk Management and Mitigation Strategies in Project Logistics
- Post-Repair Verification and Long-Term Monitoring for QA/QC

When it comes to closing out a permit after final inspection approval, particularly for foundation work, the process involves several nuanced steps that ensure compliance with local building codes and safety standards. Permit closure procedures specific to foundation work are critical because they mark the transition from construction to occupancy or further development on the site.

First, upon receiving final inspection approval, the contractor or property owner must gather all documentation related to the foundation work. This includes blueprints, engineering reports, soil tests, and any modifications made during construction that might have required additional approvals. Having a comprehensive file helps streamline the closure process as it provides concrete evidence that all work was completed according to plan and code.

Next, a formal request for permit closure must be submitted to the local building department. This request should include a cover letter summarizing the project completion, referencing the permit number, and confirming that all conditions set forth by previous inspections were met. Its often beneficial to attach photographs of the completed foundation work as visual proof of compliance.

The building department then reviews this submission. For foundation work, they pay special attention to ensuring that structural integrity has been maintained or enhanced as per design specifications. This review might involve cross-referencing with inspectors notes from previous visits or consulting with structural engineers if there were any complex issues during construction.

If everything is in order, the permit will be officially closed. This closure is not merely administrative; it legally signifies that the foundation is safe for subsequent construction phases or occupancy. The property owner receives a certificate of occupancy or completion which is crucial for insurance purposes, resale value enhancement, and future construction permissions.

However, if discrepancies are found during this review phase-perhaps an unaddressed issue from an earlier inspection-the closure might be delayed until rectifications are made and re-inspected. In such cases, communication between the contractor and building officials becomes vital to resolve issues efficiently.

In conclusion, closing out a permit after final inspection approval for foundation work involves meticulous documentation review, formal requests for closure, thorough regulatory scrutiny by local authorities, and sometimes additional corrective actions. This procedure ensures that what lies beneath our buildings-a critical component of structural safety-is built right from the ground up before moving forward with any further development or occupation of the property.

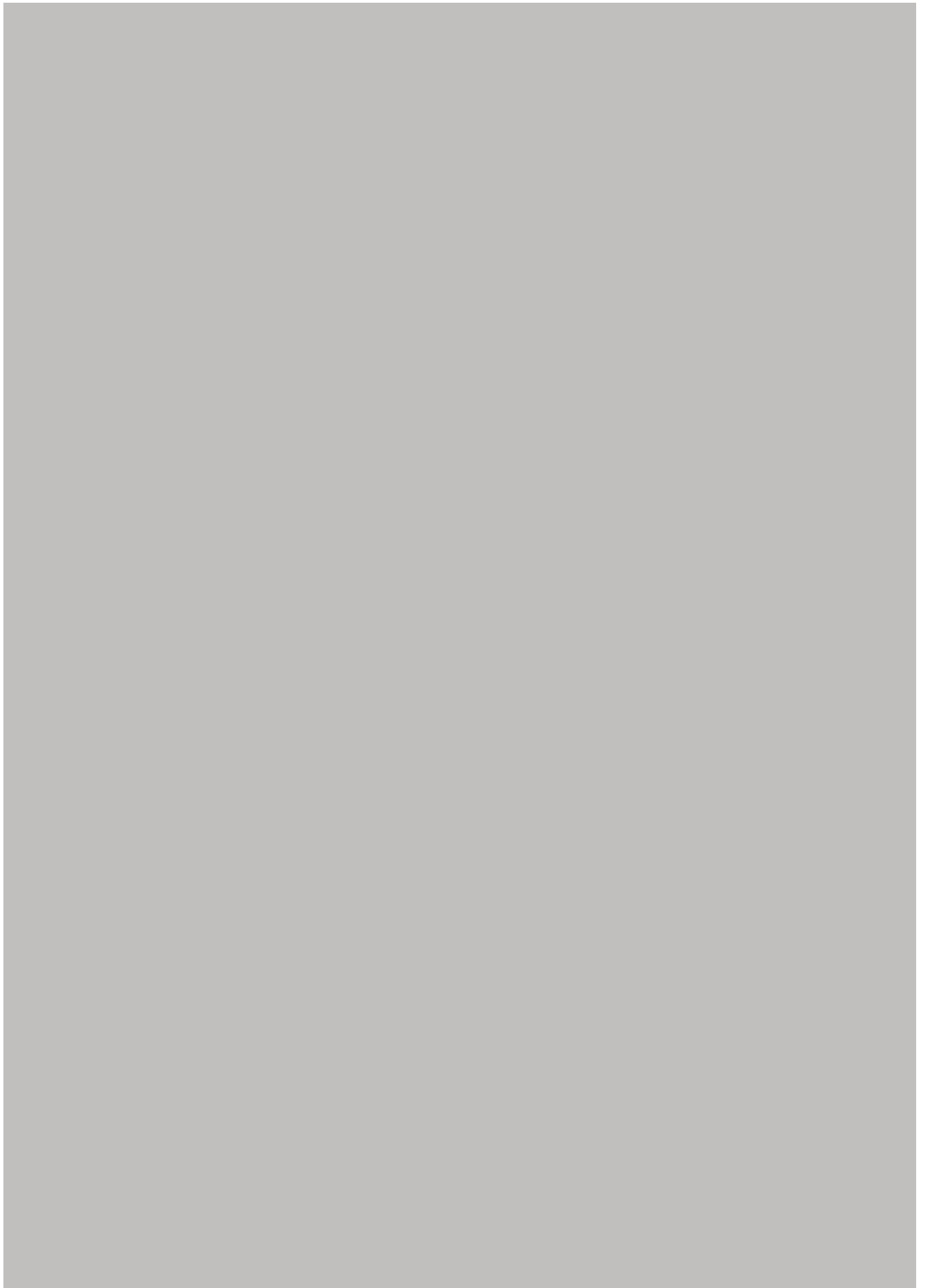
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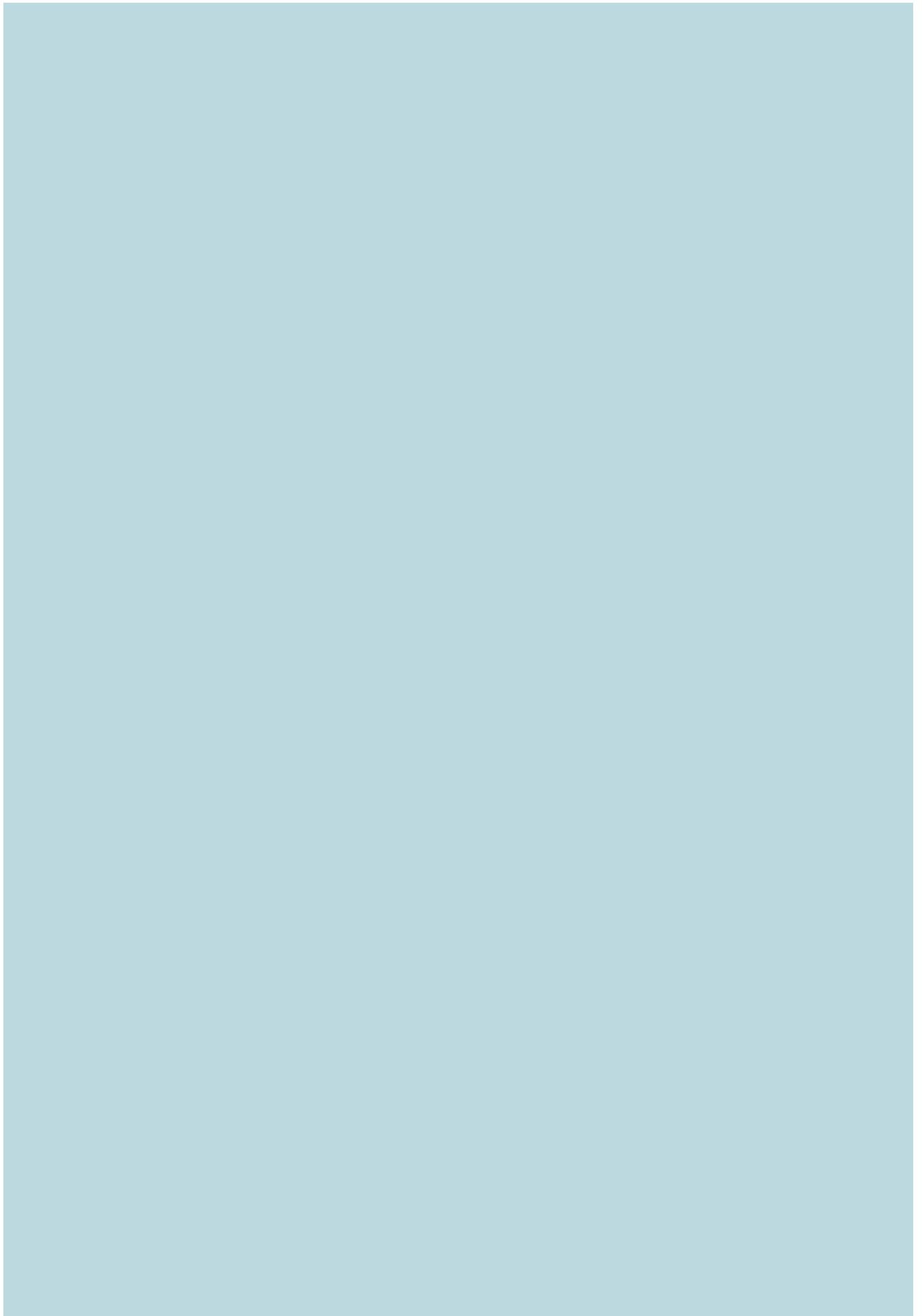
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## **Moisture: Silent Threat**



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# Material Procurement and Quality Control Procedures

Okay, so you've finally made it. The inspectors given the thumbs up on your final inspection, and it feels like the finish line is right there. But hold on just a sec, because closing out that permit isn't just about celebrating a job well done; it's about officially documenting that everything is shipshape, and that means verifying repairs and demonstrating compliance with building codes.

Think of it like this: the final inspection is the inspector saying, "Yep, looks good to me right now." Verification, on the other hand, is about providing the lasting proof. Did you actually make all the repairs they asked for? Do you have documentation showing the specific materials you used met the required standards? This is where things like receipts for materials, photos showing the completed work, and even engineers' certifications come into play.

Compliance with building codes isn't just a one-time thing for the inspection. It's a continuous thread running through the entire project. Closing out the permit is the moment you solidify that thread. You're saying, "We followed the rules every step of the way, and here's the evidence to back it up." This includes ensuring things like proper insulation R-values, fire-rated materials in the right places, and electrical wiring that meets code.

Why is all this important? Well, beyond the legal requirement of properly closing out a permit, it protects you down the line. Imagine selling your house and a future buyer discovers unpermitted work or code violations. Suddenly, you're facing potential lawsuits and costly repairs. Having that closed permit, backed by verification of repairs and compliance, provides peace of mind and protects your investment. It's the official stamp that says, "This work was done right, by the book, and everyone's safe." So, don't skip this crucial step. It's the final piece of the puzzle that ensures your project is truly complete.





# **Inspection and Testing Protocols During Foundation Repair**

Okay, so you've finally done it. The foundation repair is complete, the inspector gave it the thumbs up, and you can almost breathe easy. But there's one more, crucial step before you can truly say "mission accomplished" on that permit: getting your Certificate of Completion.

Think of this certificate as the official "all clear" signal. It's the document that definitively closes out the permit process for your foundation repair. Without it, that permit hangs open like a loose thread, potentially causing issues down the road if you ever decide to sell your place or refinance.

The process is usually pretty straightforward. Once the final inspection passes – and make absolutely sure you get that written approval from the inspector – you'll typically submit a request for the Certificate of Completion. This might involve filling out a form, possibly paying a small fee (check with your local permitting office!), and providing proof of that passed inspection.

Why is it so important? Well, it's about more than just ticking boxes. The Certificate of Completion is essentially a formal record that the work was done according to code, inspected, and approved. It gives you, and any future owners, peace of mind knowing that the foundation repair was handled properly and legally. It's a valuable piece of documentation that protects your investment and ensures compliance. So, chase down that certificate. It's the satisfying period at the end of a potentially stressful sentence.

## **About Soil mechanics**

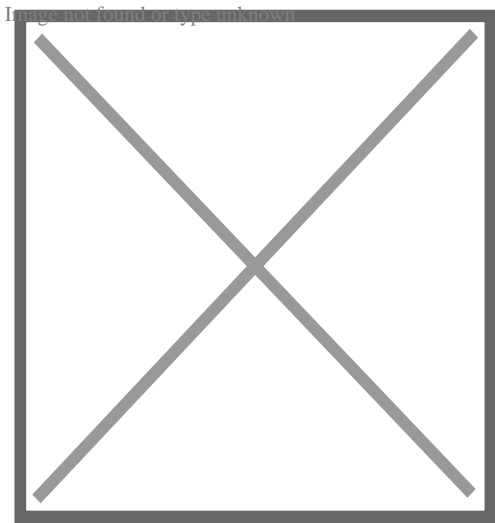
Soil mechanics is a branch of dirt physics and applied mechanics that describes the habits of soils. It varies from liquid mechanics and solid auto mechanics in the sense that soils consist of a heterogeneous mixture of fluids (typically air and water) and fragments (typically clay, silt, sand, and crushed rock) but soil may additionally have natural solids and other issue. Together with rock mechanics, dirt mechanics gives the theoretical basis for evaluation in geotechnical design, a subdiscipline of civil design, and design geology, a subdiscipline of geology. Soil technicians is used to assess the deformations of and flow of liquids within all-natural and manufactured structures that are supported on or constructed from soil, or structures that are hidden in soils. Instance applications are building and bridge structures, retaining walls, dams, and hidden pipe systems. Concepts of soil auto mechanics are additionally utilized in associated self-controls such as geophysical design, seaside engineering, farming design, and hydrology. This short article explains the genesis and composition of soil, the difference between pore water pressure and inter-granular reliable anxiety, capillary activity of liquids in the dirt pore areas, dirt category, infiltration and permeability, time reliant adjustment of volume as a

result of pressing water out of tiny pore rooms, additionally known as combination, shear toughness and rigidity of dirt. The shear stamina of dirt is primarily derived from rubbing between the particles and interlocking, which are really sensitive to the reliable stress. The post wraps up with some examples of applications of the principles of dirt mechanics such as slope security, side earth stress on preserving wall surfaces, and birthing ability of foundations.

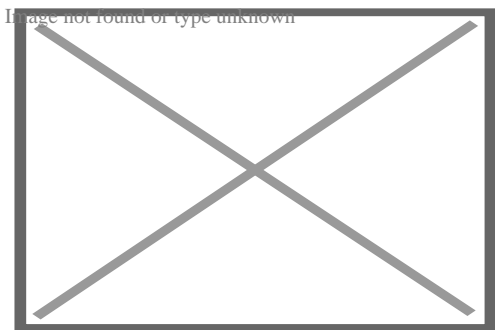
About Pump

 **The accessibility of this article is in question.** The specific issue is: **animation fails MOS, see talk.** Relevant discussion may be found on the talk page. *(April 2025)*

"Water Pump" redirects here. For the community in Pakistan, see Water Pump, Karachi. For other uses of "pump" or "pumps", see Pump (disambiguation).



A small, electrically powered pump



A large, electrically driven pump for waterworks near the Hengsteysee, Germany

A **pump** is a device that moves fluids (liquids or gases), or sometimes slurries,<sup>[1]</sup> by mechanical action, typically converted from electrical energy into hydraulic or pneumatic energy.

Mechanical pumps serve in a wide range of applications such as pumping water from wells, aquarium filtering, pond filtering and aeration, in the car industry for water-cooling and fuel injection, in the energy industry for pumping oil and natural gas or for operating cooling towers and other components of heating, ventilation and air conditioning systems. In the medical industry, pumps are used for biochemical processes in developing and manufacturing medicine, and as artificial replacements for body parts, in particular the artificial heart and penile prosthesis.

When a pump contains two or more pump mechanisms with fluid being directed to flow through them in series, it is called a *multi-stage pump*. Terms such as *two-stage* or *double-stage* may be used to specifically describe the number of stages. A pump that does not fit this description is simply a *single-stage pump* in contrast.

In biology, many different types of chemical and biomechanical pumps have evolved; biomimicry is sometimes used in developing new types of mechanical pumps.

## Types

[edit]

Mechanical pumps may be **submerged** in the fluid they are pumping or be placed **external** to the fluid.

Pumps can be classified by their method of displacement into electromagnetic pumps, positive-displacement pumps, impulse pumps, velocity pumps, gravity pumps, steam pumps and valveless pumps. There are three basic types of pumps: positive-displacement, centrifugal and axial-flow pumps. In centrifugal pumps the direction of flow of the fluid changes by ninety degrees as it flows over an impeller, while in axial flow pumps the direction of flow is unchanged.<sup>[2]</sup><sup>[3]</sup>

See also: Vacuum pump

## Electromagnetic pump

[edit]

This section is an excerpt from Electromagnetic pump.[edit]

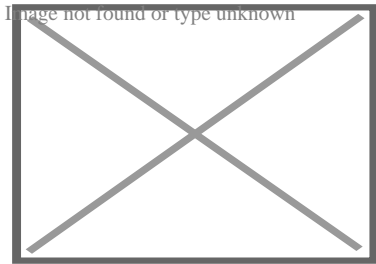
An electromagnetic pump is a pump that moves liquid metal, molten salt, brine, or other electrically conductive liquid using electromagnetism.

A magnetic field is set at right angles to the direction the liquid moves in, and a current is passed through it. This causes an electromagnetic force that moves the liquid.

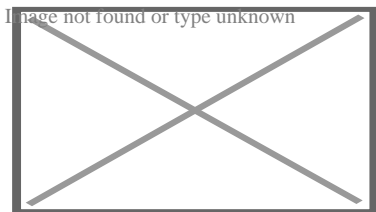
Applications include pumping molten solder in many wave soldering machines, pumping liquid-metal coolant, and magnetohydrodynamic drive.

## Positive-displacement pumps

[edit]



Lobe pump internals



Lobe pump internals

A positive-displacement pump makes a fluid move by trapping a fixed amount and forcing (displacing) that trapped volume into the discharge pipe.

Some positive-displacement pumps use an expanding cavity on the suction side and a decreasing cavity on the discharge side. Liquid flows into the pump as the cavity on the suction side expands and the liquid flows out of the discharge as the cavity collapses. The volume is constant through each cycle of operation.

## Positive-displacement pump behavior and safety

[edit]

Positive-displacement pumps, unlike centrifugal, can theoretically produce the same flow at a given rotational speed no matter what the discharge pressure. Thus, positive-displacement pumps are *constant flow machines*. However, a slight increase in internal leakage as the pressure increases prevents a truly constant flow rate.

A positive-displacement pump must not operate against a closed valve on the discharge side of the pump, because it has no shutoff head like centrifugal pumps. A positive-displacement pump operating against a closed discharge valve continues to produce flow and the pressure in the discharge line increases until the line bursts, the pump is severely damaged, or both.

A relief or safety valve on the discharge side of the positive-displacement pump is therefore necessary. The relief valve can be internal or external. The pump manufacturer normally has the option to supply internal relief or safety valves. The internal valve is usually used only as a safety precaution. An external relief valve in the discharge line, with a return line back to the suction line or supply tank, provides increased safety.

## Positive-displacement types

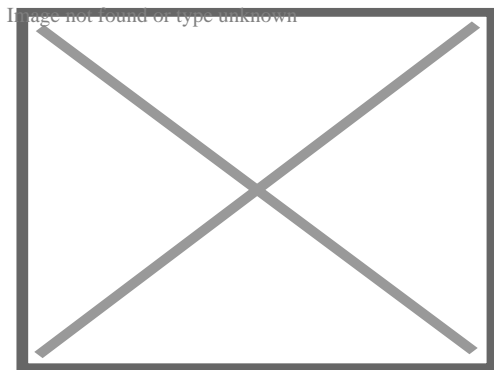
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A positive-displacement pump can be further classified according to the mechanism used to move the fluid:

- *Rotary-type* positive displacement: internal and external gear pump, screw pump, lobe pump, shuttle block, flexible vane and sliding vane, circumferential piston, flexible impeller, helical twisted roots (e.g. the Wendelkolben pump) and liquid-ring pumps
- *Reciprocating-type* positive displacement: piston pumps, plunger pumps and diaphragm pumps
- *Linear-type* positive displacement: rope pumps and chain pumps

## Rotary positive-displacement pumps

[edit]



Rotary vane pump

These pumps move fluid using a rotating mechanism that creates a vacuum that captures and draws in the liquid.[<sup>4</sup>]

*Advantages:* Rotary pumps are very efficient[<sup>5</sup>] because they can handle highly viscous fluids with higher flow rates as viscosity increases.[<sup>6</sup>]

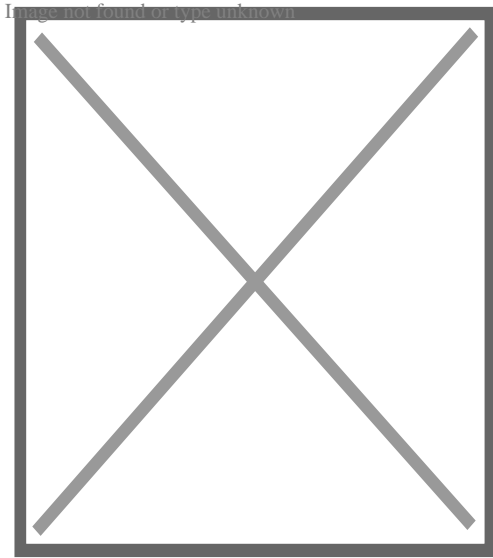
*Drawbacks:* The nature of the pump requires very close clearances between the rotating pump and the outer edge, making it rotate at a slow, steady speed. If rotary pumps are operated at high speeds, the fluids cause erosion, which eventually causes enlarged clearances that liquid can pass through, which reduces efficiency.

Rotary positive-displacement pumps fall into five main types:

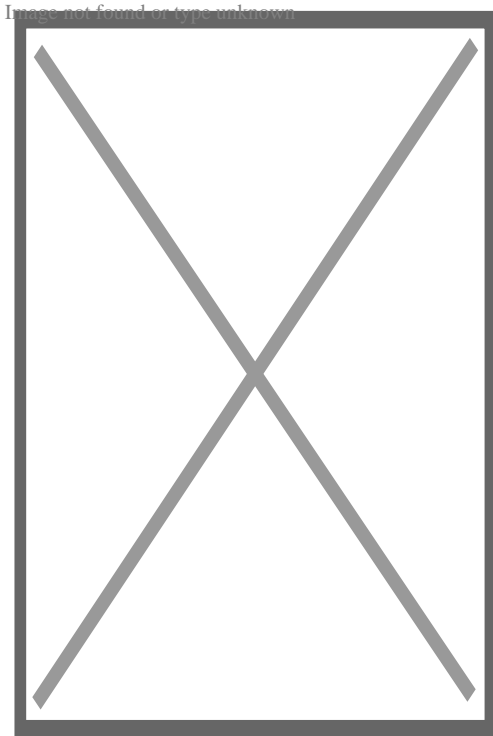
- Gear pumps – a simple type of rotary pump where the liquid is pushed around a pair of gears.
- Screw pumps – the shape of the internals of this pump is usually two screws turning against each other to pump the liquid
- Rotary vane pumps
- Hollow disc pumps (also known as eccentric disc pumps or hollow rotary disc pumps), similar to scroll compressors, these have an eccentric cylindrical rotor encased in a circular housing. As the rotor orbits, it traps fluid between the rotor and the casing, drawing the fluid through the pump. It is used for highly viscous fluids like petroleum-derived products, and it can also support high pressures of up to 290 psi.[<sup>7</sup>][<sup>8</sup>][<sup>9</sup>][<sup>10</sup>][<sup>11</sup>][<sup>12</sup>][<sup>13</sup>]
- Peristaltic pumps have rollers which pinch a section of flexible tubing, forcing the liquid ahead as the rollers advance. Because they are very easy to keep clean, these are popular for dispensing food, medicine, and concrete.

## **Reciprocating positive-displacement pumps**

[edit]



Simple hand pump



Antique "pitcher" pump (c. 1924) at the Colored School in Alapaha, Georgia, US

See also: Reciprocating pump

Reciprocating pumps move the fluid using one or more oscillating pistons, plungers, or membranes (diaphragms), while valves restrict fluid motion to the desired direction. In order for suction to take place, the pump must first pull the plunger in an outward motion to decrease pressure in the chamber. Once the plunger pushes back, it will increase the chamber pressure and the inward pressure of the plunger will then open the discharge

valve and release the fluid into the delivery pipe at constant flow rate and increased pressure.

Pumps in this category range from *simplex*, with one cylinder, to in some cases *quad* (four) cylinders, or more. Many reciprocating-type pumps are *duplex* (two) or *triplex* (three) cylinder. They can be either *single-acting* with suction during one direction of piston motion and discharge on the other, or *double-acting* with suction and discharge in both directions. The pumps can be powered manually, by air or steam, or by a belt driven by an engine. This type of pump was used extensively in the 19th century—in the early days of steam propulsion—as boiler feed water pumps. Now reciprocating pumps typically pump highly viscous fluids like concrete and heavy oils, and serve in special applications that demand low flow rates against high resistance. Reciprocating hand pumps were widely used to pump water from wells. Common bicycle pumps and foot pumps for inflation use reciprocating action.

These positive-displacement pumps have an expanding cavity on the suction side and a decreasing cavity on the discharge side. Liquid flows into the pumps as the cavity on the suction side expands and the liquid flows out of the discharge as the cavity collapses. The volume is constant given each cycle of operation and the pump's volumetric efficiency can be achieved through routine maintenance and inspection of its valves<sup>[14]</sup>

Typical reciprocating pumps are:

- *Plunger pump* – a reciprocating plunger pushes the fluid through one or two open valves, closed by suction on the way back.
- *Diaphragm pump* – similar to plunger pumps, where the plunger pressurizes hydraulic oil which is used to flex a diaphragm in the pumping cylinder. Diaphragm valves are used to pump hazardous and toxic fluids.
- *Piston pump displacement pumps* – *usually simple devices for pumping small amounts of liquid or gel manually. The common hand soap dispenser is such a pump.*
- *Radial piston pump* – a form of hydraulic pump where pistons extend in a radial direction.
- *Vibratory pump or vibration pump* – a particularly low-cost form of plunger pump, popular in low-cost espresso machines.<sup>[15][16]</sup> The only moving part is a spring-loaded piston, the armature of a solenoid. Driven by half-wave rectified alternating current, the piston is forced forward while energized, and is retracted by the spring during the other half cycle. Due to their inefficiency, vibratory pumps typically cannot be operated for more than one minute without overheating, so are limited to intermittent duty.

## **Various positive-displacement pumps**

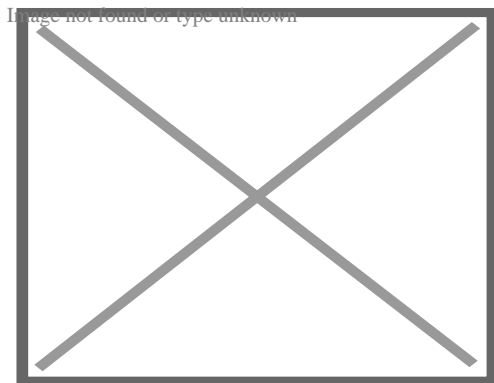
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The positive-displacement principle applies in these pumps:

- Rotary lobe pump
- Progressing cavity pump
- Rotary gear pump
- Piston pump
- Diaphragm pump
- Screw pump
- Gear pump
- Hydraulic pump
- Rotary vane pump
- Peristaltic pump
- Rope pump
- Flexible impeller pump

## **Gear pump**

[edit]



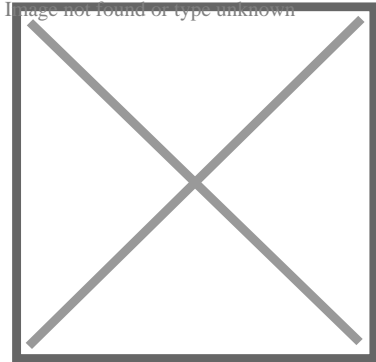
Gear pump

Main article: Gear pump

This is the simplest form of rotary positive-displacement pumps. It consists of two meshed gears that rotate in a closely fitted casing. The tooth spaces trap fluid and force it around the outer periphery. The fluid does not travel back on the meshed part, because the teeth mesh closely in the center. Gear pumps see wide use in car engine oil pumps and in various hydraulic power packs.

## Screw pump

[edit]



Screw pump

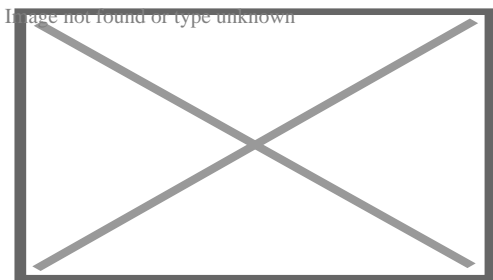
Main article: Screw pump

A screw pump is a more complicated type of rotary pump that uses two or three screws with opposing thread — e.g., one screw turns clockwise and the other counterclockwise. The screws are mounted on parallel shafts that often have gears that mesh so the shafts turn together and everything stays in place. In some cases the driven screw drives the secondary screw, without gears, often using the fluid to limit abrasion. The screws turn on the shafts and drive fluid through the pump. As with other forms of rotary pumps, the clearance between moving parts and the pump's casing is minimal.

## Progressing cavity pump

[edit]

Main article: Progressing cavity pump

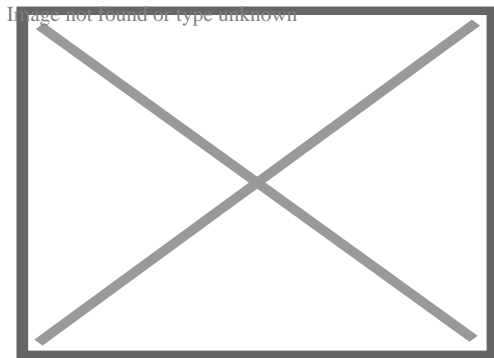


Progressing cavity pump

Widely used for pumping difficult materials, such as sewage sludge contaminated with large particles, a progressing cavity pump consists of a helical rotor, about ten times as long as its width, and a stator, mainly made out of rubber. This can be visualized as a central core of diameter  $x$  with, typically, a curved spiral wound around of thickness half  $x$ , though in reality it is manufactured in a single lobe. This shaft fits inside a heavy-duty rubber sleeve or stator, of wall thickness also typically  $x$ . As the shaft rotates inside the stator, the rotor gradually forces fluid up the rubber cavity. Such pumps can develop very high pressure at low volumes at a rate of 90 PSI per stage on water for standard configurations.

## Roots-type pump

[edit]



A Roots lobe pump

Main article: Roots-type supercharger

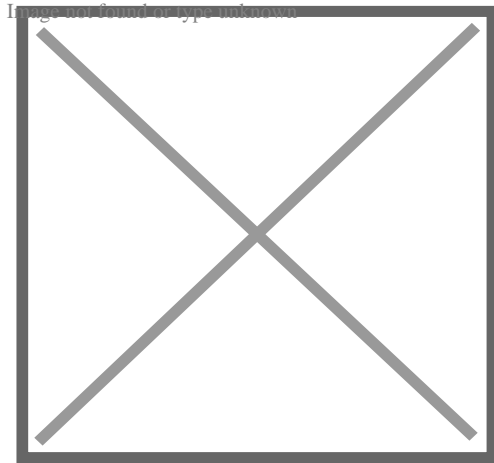
Named after the Roots brothers who invented it, this lobe pump displaces the fluid trapped between two long helical rotors, each fitted into the other when perpendicular at  $90^\circ$ , rotating inside a triangular shaped sealing line configuration, both at the point of suction and at the point of discharge. This design produces a continuous flow with equal volume and no vortex. It can work at low pulsation rates, and offers gentle performance that some applications require.

Applications include:

- High capacity industrial air compressors.
- Roots superchargers on internal combustion engines.
- A brand of civil defense siren, the Federal Signal Corporation's Thunderbolt.

## Peristaltic pump

[edit]



360° peristaltic pump

Main article: Peristaltic pump

A *peristaltic pump* is a type of positive-displacement pump. It contains fluid within a flexible tube fitted inside a circular pump casing (though linear peristaltic pumps have been made). A number of *rollers*, *shoes*, or *wipers* attached to a rotor compress the flexible tube. As the rotor turns, the part of the tube under compression closes (or *occludes*), forcing the fluid through the tube. Additionally, when the tube opens to its natural state after the passing of the cam it draws (*restitution*) fluid into the pump. This process is called *peristalsis* and is used in many biological systems such as the gastrointestinal tract.

## Plunger pumps

[edit]

Main article: Plunger pump

*Plunger pumps* are reciprocating positive-displacement pumps.

These consist of a cylinder with a reciprocating plunger. The suction and discharge valves are mounted in the head of the cylinder. In the suction stroke, the plunger retracts

and the suction valves open causing suction of fluid into the cylinder. In the forward stroke, the plunger pushes the liquid out of the discharge valve. Efficiency and common problems: With only one cylinder in plunger pumps, the fluid flow varies between maximum flow when the plunger moves through the middle positions, and zero flow when the plunger is at the end positions. A lot of energy is wasted when the fluid is accelerated in the piping system. Vibration and *water hammer* may be a serious problem. In general, the problems are compensated for by using two or more cylinders not working in phase with each other. Centrifugal pumps are also susceptible to water hammer. Surge analysis, a specialized study, helps evaluate this risk in such systems.

## Triplex-style plunger pump

[edit]

Triplex plunger pumps use three plungers, which reduces the pulsation relative to single reciprocating plunger pumps. Adding a pulsation dampener on the pump outlet can further smooth the *pump ripple*, or ripple graph of a pump transducer. The dynamic relationship of the high-pressure fluid and plunger generally requires high-quality plunger seals. Plunger pumps with a larger number of plungers have the benefit of increased flow, or smoother flow without a pulsation damper. The increase in moving parts and crankshaft load is one drawback.

Car washes often use these triplex-style plunger pumps (perhaps without pulsation dampers). In 1968, William Bruggeman reduced the size of the triplex pump and increased the lifespan so that car washes could use equipment with smaller footprints. Durable high-pressure seals, low-pressure seals and oil seals, hardened crankshafts, hardened connecting rods, thick ceramic plungers and heavier duty ball and roller bearings improve reliability in triplex pumps. Triplex pumps now are in a myriad of markets across the world.

Triplex pumps with shorter lifetimes are commonplace to the home user. A person who uses a home pressure washer for 10 hours a year may be satisfied with a pump that lasts 100 hours between rebuilds. Industrial-grade or continuous duty triplex pumps on the other end of the quality spectrum may run for as much as 2,080 hours a year.<sup>[17]</sup>

The oil and gas drilling industry uses massive semi-trailer-transported triplex pumps called mud pumps to pump drilling mud, which cools the drill bit and carries the cuttings back to the surface.<sup>[18]</sup> Drillers use triplex or even quintuplex pumps to inject water and solvents deep into shale in the extraction process called *fracking*.<sup>[19]</sup>

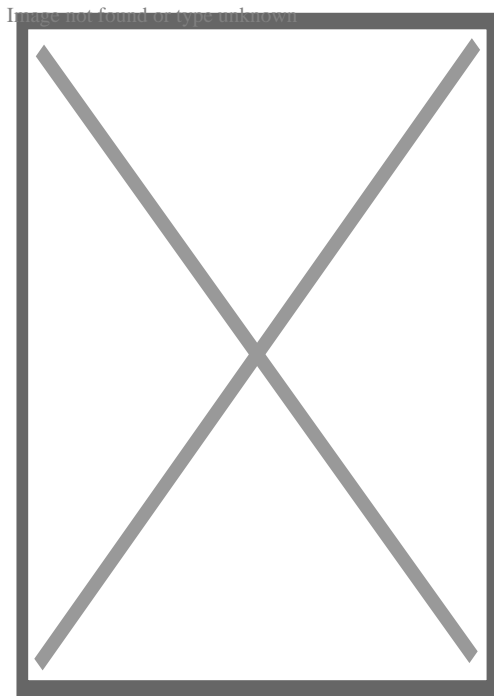
## Diaphragm pump

[edit]

Typically run on electricity compressed air, diaphragm pumps are relatively inexpensive and can perform a wide variety of duties, from pumping air into an aquarium, to liquids through a filter press. Double-diaphragm pumps can handle viscous fluids and abrasive materials with a gentle pumping process ideal for transporting shear-sensitive media.<sup>[20]</sup>

## Rope pump

[edit]



Rope pump schematic

Main article: Rope pump

Devised in China as chain pumps over 1000 years ago, these pumps can be made from very simple materials: A rope, a wheel and a pipe are sufficient to make a simple rope pump. Rope pump efficiency has been studied by grassroots organizations and the techniques for making and running them have been continuously improved.<sup>[21]</sup>

## Impulse pump

[edit]

Impulse pumps use pressure created by gas (usually air). In some impulse pumps the gas trapped in the liquid (usually water), is released and accumulated somewhere in the pump, creating a pressure that can push part of the liquid upwards.

Conventional impulse pumps include:

- *Hydraulic ram pumps* – kinetic energy of a low-head water supply is stored temporarily in an air-bubble hydraulic accumulator, then used to drive water to a higher head.
- *Pulser pumps* – run with natural resources, by kinetic energy only.
- *Airlift pumps* – run on air inserted into pipe, which pushes the water up when bubbles move upward

Instead of a gas accumulation and releasing cycle, the pressure can be created by burning of hydrocarbons. Such combustion driven pumps directly transmit the impulse from a combustion event through the actuation membrane to the pump fluid. In order to allow this direct transmission, the pump needs to be almost entirely made of an elastomer (e.g. silicone rubber). Hence, the combustion causes the membrane to expand and thereby pumps the fluid out of the adjacent pumping chamber. The first combustion-driven soft pump was developed by ETH Zurich.<sup>[22]</sup>

## Hydraulic ram pump

[edit]

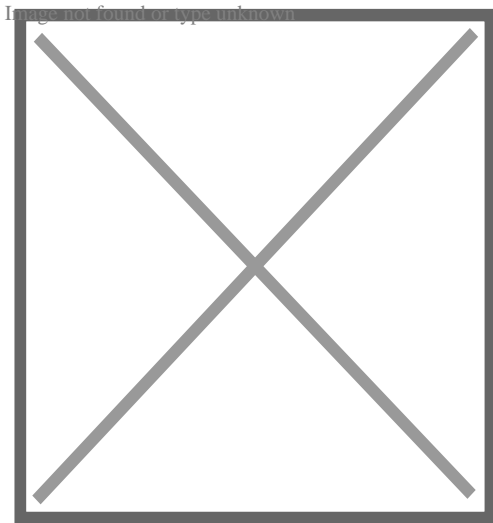
A hydraulic ram is a water pump powered by hydropower.<sup>[23]</sup>

It takes in water at relatively low pressure and high flow-rate and outputs water at a higher hydraulic-head and lower flow-rate. The device uses the water hammer effect to develop pressure that lifts a portion of the input water that powers the pump to a point higher than where the water started.

The hydraulic ram is sometimes used in remote areas, where there is both a source of low-head hydropower, and a need for pumping water to a destination higher in elevation than the source. In this situation, the ram is often useful, since it requires no outside source of power other than the kinetic energy of flowing water.

## Velocity pumps

[edit]



A centrifugal pump uses an impeller with backward-swept arms

Rotodynamic pumps (or dynamic pumps) are a type of velocity pump in which kinetic energy is added to the fluid by increasing the flow velocity. This increase in energy is converted to a gain in potential energy (pressure) when the velocity is reduced prior to or as the flow exits the pump into the discharge pipe. This conversion of kinetic energy to pressure is explained by the *First law of thermodynamics*, or more specifically by *Bernoulli's principle*.

Dynamic pumps can be further subdivided according to the means in which the velocity gain is achieved.<sup>[24]</sup>

These types of pumps have a number of characteristics:

1. Continuous energy
2. Conversion of added energy to increase in kinetic energy (increase in velocity)
3. Conversion of increased velocity (kinetic energy) to an increase in pressure head

A practical difference between dynamic and positive-displacement pumps is how they operate under closed valve conditions. Positive-displacement pumps physically displace fluid, so closing a valve downstream of a positive-displacement pump produces a continual pressure build up that can cause mechanical failure of pipeline or pump. Dynamic pumps differ in that they can be safely operated under closed valve conditions (for short periods of time).

## Radial-flow pump

[edit]

Such a pump is also referred to as a *centrifugal pump*. The fluid enters along the axis or center, is accelerated by the impeller and exits at right angles to the shaft (radially); an example is the centrifugal fan, which is commonly used to implement a vacuum cleaner. Another type of radial-flow pump is a vortex pump. The liquid in them moves in tangential direction around the working wheel. The conversion from the mechanical energy of motor into the potential energy of flow comes by means of multiple whirls, which are excited by the impeller in the working channel of the pump. Generally, a radial-flow pump operates at higher pressures and lower flow rates than an axial- or a mixed-flow pump.

## Axial-flow pump

[edit]

Main article: Axial-flow pump

These are also referred to as *all-fluid pumps*. The fluid is pushed outward or inward to move fluid axially. They operate at much lower pressures and higher flow rates than radial-flow (centrifugal) pumps. Axial-flow pumps cannot be run up to speed without special precaution. If at a low flow rate, the total head rise and high torque associated with this pipe would mean that the starting torque would have to become a function of acceleration for the whole mass of liquid in the pipe system.<sup>[25]</sup>

Mixed-flow pumps function as a compromise between radial and axial-flow pumps. The fluid experiences both radial acceleration and lift and exits the impeller somewhere between 0 and 90 degrees from the axial direction. As a consequence mixed-flow pumps operate at higher pressures than axial-flow pumps while delivering higher discharges than radial-flow pumps. The exit angle of the flow dictates the pressure head-discharge characteristic in relation to radial and mixed-flow.

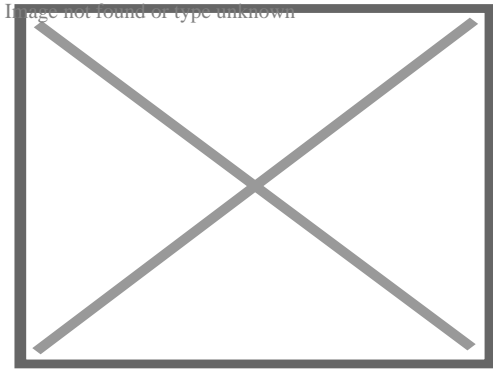
## Regenerative turbine pump

[edit]

Regenerative turbine pump animation

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Regenerative turbine pump animation



Close-up of a Regenerative Turbine Pump Impeller

Also known as **drag**, **friction**, **liquid-ring pump**, **peripheral**, **traction**, **turbulence**, or **vortex** pumps, regenerative turbine pumps are a class of rotodynamic pump that operates at high head pressures, typically 4–20 bars (400–2,000 kPa; 58–290 psi).<sup>[26]</sup>

The pump has an impeller with a number of vanes or paddles which spins in a cavity. The suction port and pressure ports are located at the perimeter of the cavity and are isolated by a barrier called a **stripper**, which allows only the **tip channel** (fluid between the blades) to recirculate, and forces any fluid in the **side channel** (fluid in the cavity outside of the blades) through the pressure port. In a regenerative turbine pump, as fluid spirals repeatedly from a vane into the side channel and back to the next vane, kinetic energy is imparted to the periphery,<sup>[26]</sup> thus pressure builds with each spiral, in a manner similar to a regenerative blower.<sup>[27][28][29]</sup>

As regenerative turbine pumps cannot become vapor locked, they are commonly applied to volatile, hot, or cryogenic fluid transport. However, as tolerances are typically tight, they are vulnerable to solids or particles causing jamming or rapid wear. Efficiency is typically low, and pressure and power consumption typically decrease with flow. Additionally, pumping direction can be reversed by reversing direction of spin.<sup>[29][27][30]</sup>

## Side-channel pump

[edit]

A **side-channel** pump has a suction disk, an impeller, and a discharge disk.<sup>[31]</sup>

## Eductor-jet pump

[edit]

Main article: Eductor-jet pump

This uses a jet, often of steam, to create a low pressure. This low pressure sucks in fluid and propels it into a higher-pressure region.

## Gravity pumps

[edit]

Gravity pumps include the *syphon* and *Heron's fountain*. The *hydraulic ram* is also sometimes called a gravity pump. In a gravity pump the fluid is lifted by gravitational force.

## Steam pump

[edit]

Steam pumps have been for a long time mainly of historical interest. They include any type of pump powered by a steam engine and also pistonless pumps such as Thomas Savery's or the Pulsometer steam pump.

Recently there has been a resurgence of interest in low-power solar steam pumps for use in smallholder irrigation in developing countries. Previously small steam engines have not been viable because of escalating inefficiencies as vapour engines decrease in size. However the use of modern engineering materials coupled with alternative engine configurations has meant that these types of system are now a cost-effective opportunity.

## Valveless pumps

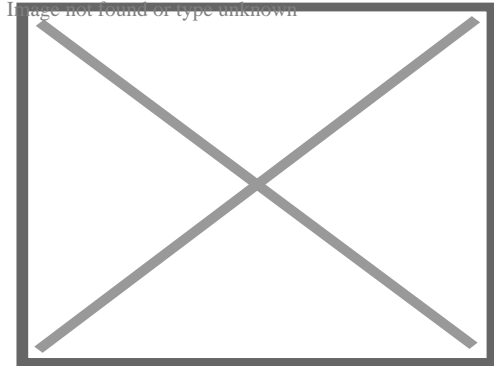
[edit]

Valveless pumping assists in fluid transport in various biomedical and engineering systems. In a valveless pumping system, no valves (or physical occlusions) are present to regulate the flow direction. The fluid pumping efficiency of a valveless system, however, is not necessarily lower than that having valves. In fact, many fluid-dynamical systems in nature and engineering more or less rely upon valveless pumping to transport the working fluids therein. For instance, blood circulation in the cardiovascular system is maintained to some extent even when the heart's valves fail. Meanwhile, the embryonic vertebrate heart begins pumping blood long before the development of discernible chambers and valves. Similar to blood circulation in one direction, bird respiratory systems pump air in one direction in rigid lungs, but without any physiological valve. In microfluidics, valveless impedance pumps have been fabricated, and are expected to be particularly suitable for handling sensitive biofluids. Ink jet printers operating on the piezoelectric transducer principle also use valveless pumping. The pump chamber is

emptied through the printing jet due to reduced flow impedance in that direction and refilled by capillary action.

## Pump repairs

[edit]



Derelict windmill connected to water pump with water storage tank in the foreground

Examining pump repair records and mean time between failures (MTBF) is of great importance to responsible and conscientious pump users. In view of that fact, the preface to the 2006 Pump User's Handbook alludes to "pump failure" statistics. For the sake of convenience, these failure statistics often are translated into MTBF (in this case, installed life before failure).[<sup>32</sup>]

In early 2005, Gordon Buck, John Crane Inc.'s chief engineer for field operations in Baton Rouge, Louisiana, examined the repair records for a number of refinery and chemical plants to obtain meaningful reliability data for centrifugal pumps. A total of 15 operating plants having nearly 15,000 pumps were included in the survey. The smallest of these plants had about 100 pumps; several plants had over 2000. All facilities were located in the United States. In addition, considered as "new", others as "renewed" and still others as "established". Many of these plants—but not all—had an alliance arrangement with John Crane. In some cases, the alliance contract included having a John Crane Inc. technician or engineer on-site to coordinate various aspects of the program.

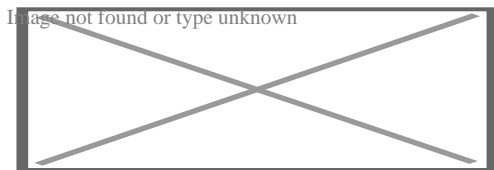
Not all plants are refineries, however, and different results occur elsewhere. In chemical plants, pumps have historically been "throw-away" items as chemical attack limits life. Things have improved in recent years, but the somewhat restricted space available in "old" DIN and ASME-standardized stuffing boxes places limits on the type of seal that fits. Unless the pump user upgrades the seal chamber, the pump only accommodates more compact and simple versions. Without this upgrading, lifetimes in chemical installations are generally around 50 to 60 percent of the refinery values.

Unscheduled maintenance is often one of the most significant costs of ownership, and failures of mechanical seals and bearings are among the major causes. Keep in mind the potential value of selecting pumps that cost more initially, but last much longer between repairs. The MTBF of a better pump may be one to four years longer than that of its non-upgraded counterpart. Consider that published average values of avoided pump failures range from US\$2600 to US\$12,000. This does not include lost opportunity costs. One pump fire occurs per 1000 failures. Having fewer pump failures means having fewer destructive pump fires.

As has been noted, a typical pump failure, based on actual year 2002 reports, costs US\$5,000 on average. This includes costs for material, parts, labor and overhead. Extending a pump's MTBF from 12 to 18 months would save US\$1,667 per year — which might be greater than the cost to upgrade the centrifugal pump's reliability.<sup>[32][1][33]</sup>

## Applications

[edit]



Metering pump for gasoline and additives

Pumps are used throughout society for a variety of purposes. Early applications includes the use of the windmill or watermill to pump water. Today, the pump is used for irrigation, water supply, gasoline supply, air conditioning systems, refrigeration (usually called a compressor), chemical movement, sewage movement, flood control, marine services, etc.

Because of the wide variety of applications, pumps have a plethora of shapes and sizes: from very large to very small, from handling gas to handling liquid, from high pressure to low pressure, and from high volume to low volume.

## Priming a pump

[edit]

Typically, a liquid pump cannot simply draw air. The feed line of the pump and the internal body surrounding the pumping mechanism must first be filled with the liquid that requires pumping: An operator must introduce liquid into the system to initiate the pumping, known as *priming* the pump. Loss of prime is usually due to ingestion of air into the pump, or evaporation of the working fluid if the pump is used infrequently.

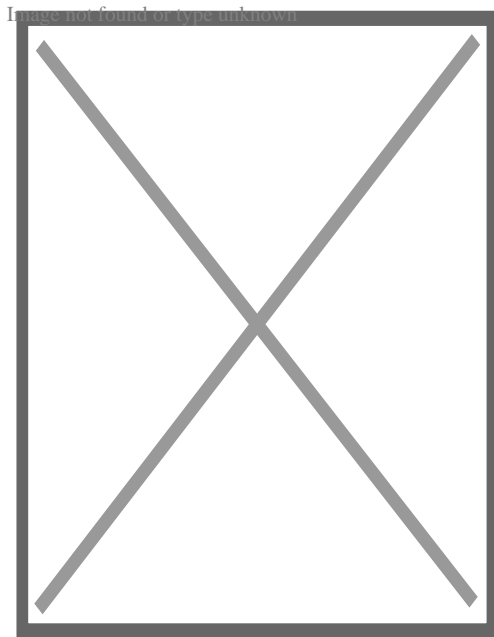
Clearances and displacement ratios in pumps for liquids are insufficient for pumping compressible gas, so air or other gasses in the pump can not be evacuated by the pump's action alone. This is the case with most velocity (rotodynamic) pumps — for example, centrifugal pumps. For such pumps, the position of the pump and intake tubing should be lower than the suction point so it is primed by gravity; otherwise the pump should be manually filled with liquid or a secondary pump should be used until all air is removed from the suction line and the pump casing. Liquid ring pumps have a dedicated intake for the priming liquid separate from the intake of the fluid being pumped, as the fluid being pumped may be a gas or mix of gas, liquid, and solids. For these pumps the priming liquid intake must be supplied continuously (either by gravity or pressure), however the intake for the fluid being pumped is capable of drawing a vacuum equivalent to the boiling point of the priming liquid.<sup>[34]</sup>

Positive-displacement pumps, however, tend to have sufficiently tight sealing between the moving parts and the casing or housing of the pump that they can be described as *self-priming*. Such pumps can also serve as *priming pumps*, so-called when they are used to fulfill that need for other pumps in lieu of action taken by a human operator.

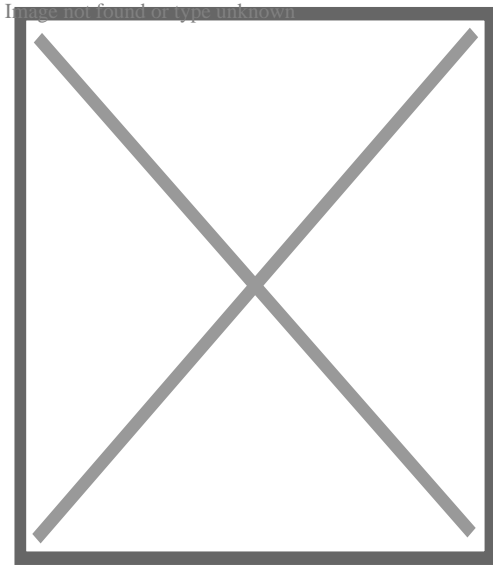
## Pumps as public water supplies

[edit]

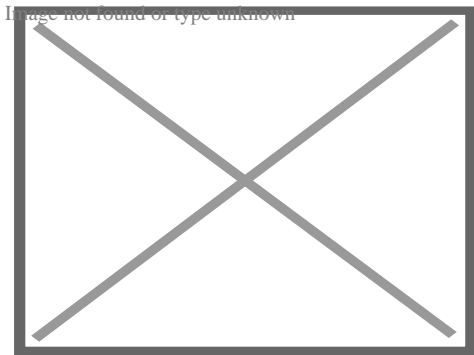
Main article: Hand pump



Arabic depiction of a piston pump, by Al-Jazari, c. 1206<sup>[35]</sup><sup>[36]</sup>



First European depiction of a piston pump, by Taccola, c. 1450<sup>[37]</sup>



Irrigation is underway by pump-enabled extraction directly from the Gumti, seen in the background, in Comilla, Bangladesh.

One sort of pump once common worldwide was a hand-powered water pump, or 'pitcher pump'. It was commonly installed over community water wells in the days before piped water supplies.

In parts of the British Isles, it was often called *the parish pump*. Though such community pumps are no longer common, people still used the expression *parish pump* to describe a place or forum where matters of local interest are discussed.<sup>[38]</sup>

Because water from pitcher pumps is drawn directly from the soil, it is more prone to contamination. If such water is not filtered and purified, consumption of it might lead to gastrointestinal or other water-borne diseases. A notorious case is the 1854 Broad Street cholera outbreak. At the time it was not known how cholera was transmitted, but physician John Snow suspected contaminated water and had the handle of the public pump he suspected removed; the outbreak then subsided.

Modern hand-operated community pumps are considered the most sustainable low-cost option for safe water supply in resource-poor settings, often in rural areas in developing

countries. A hand pump opens access to deeper groundwater that is often not polluted and also improves the safety of a well by protecting the water source from contaminated buckets. Pumps such as the Afridev pump are designed to be cheap to build and install, and easy to maintain with simple parts. However, scarcity of spare parts for these type of pumps in some regions of Africa has diminished their utility for these areas.

## **Sealing multiphase pumping applications**

[edit]

Multiphase pumping applications, also referred to as tri-phase, have grown due to increased oil drilling activity. In addition, the economics of multiphase production is attractive to upstream operations as it leads to simpler, smaller in-field installations, reduced equipment costs and improved production rates. In essence, the multiphase pump can accommodate all fluid stream properties with one piece of equipment, which has a smaller footprint. Often, two smaller multiphase pumps are installed in series rather than having just one massive pump.

## **Types and features of multiphase pumps**

[edit]

### **Helico-axial (centrifugal)**

[edit]

A rotodynamic pump with one single shaft that requires two mechanical seals, this pump uses an open-type axial impeller. It is often called a *Poseidon pump*, and can be described as a cross between an axial compressor and a centrifugal pump.

### **Twin-screw (positive-displacement)**

[edit]

The twin-screw pump is constructed of two inter-meshing screws that move the pumped fluid. Twin screw pumps are often used when pumping conditions contain high gas volume fractions and fluctuating inlet conditions. Four mechanical seals are required to seal the two shafts.

## Progressive cavity (positive-displacement)

[edit]

Progressive Cavity Pumps are well suited to pump sludge, slurries, viscous, and shear sensitive fluids. [39] Progressive cavity pumps are single-screw types use in surface and downhole oil production.[40] They serve a vast arrange of industries and applications ranging from Wastewater Treatment,[41] Pulp and Paper, oil and gas, mining, and oil and gas.

## Electric submersible (centrifugal)

[edit]

These pumps are basically multistage centrifugal pumps and are widely used in oil well applications as a method for artificial lift. These pumps are usually specified when the pumped fluid is mainly liquid.

*Buffer tank* A buffer tank is often installed upstream of the pump suction nozzle in case of a slug flow. The buffer tank breaks the energy of the liquid slug, smooths any fluctuations in the incoming flow and acts as a sand trap.

As the name indicates, multiphase pumps and their mechanical seals can encounter a large variation in service conditions such as changing process fluid composition, temperature variations, high and low operating pressures and exposure to abrasive/erosive media. The challenge is selecting the appropriate mechanical seal arrangement and support system to ensure maximized seal life and its overall effectiveness.[42][43][44]

## Specifications

[edit]

Pumps are commonly rated by horsepower, volumetric flow rate, outlet pressure in metres (or feet) of head, inlet suction in suction feet (or metres) of head. The head can be simplified as the number of feet or metres the pump can raise or lower a column of water at atmospheric pressure.

From an initial design point of view, engineers often use a quantity termed the specific speed to identify the most suitable pump type for a particular combination of flow rate and head. Net Positive Suction Head (NPSH) is crucial for pump performance. It has two

key aspects: 1) NPSHr (Required): The Head required for the pump to operate without cavitation issues. 2) NPSHa (Available): The actual pressure provided by the system (e.g., from an overhead tank). For optimal pump operation, NPSHa must always exceed NPSHr. This ensures the pump has enough pressure to prevent cavitation, a damaging condition.

## Pumping power

[edit]

Main article: Bernoulli's equation

The power imparted into a fluid increases the energy of the fluid per unit volume. Thus the power relationship is between the conversion of the mechanical energy of the pump mechanism and the fluid elements within the pump. In general, this is governed by a series of simultaneous differential equations, known as the Navier–Stokes equations. However a more simple equation relating only the different energies in the fluid, known as Bernoulli's equation can be used. Hence the power,  $P$ , required by the pump:

$$P = \frac{\Delta p Q}{\eta}$$

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where  $\Delta p$  is the change in total pressure between the inlet and outlet (in Pa), and  $Q$ , the volume flow-rate of the fluid is given in m<sup>3</sup>/s. The total pressure may have gravitational, static pressure and kinetic energy components; i.e. energy is distributed between change in the fluid's gravitational potential energy (going up or down hill), change in velocity, or change in static pressure.  $\eta$  is the pump efficiency, and may be given by the manufacturer's information, such as in the form of a pump curve, and is typically derived from either fluid dynamics simulation (i.e. solutions to the Navier–Stokes for the particular pump geometry), or by testing. The efficiency of the pump depends upon the pump's configuration and operating conditions (such as rotational speed, fluid density and viscosity etc.)

$$\Delta p = \rho \frac{(v_2^2 - v_1^2)}{2} + \rho \Delta z + \Delta p_{\mathrm{static}}$$

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For a typical "pumping" configuration, the work is imparted on the fluid, and is thus positive. For the fluid imparting the work on the pump (i.e. a turbine), the work is negative. Power required to drive the pump is determined by dividing the output power by the pump efficiency. Furthermore, this definition encompasses pumps with no moving parts, such as a siphon.

## Efficiency

[edit]

Pump efficiency is defined as the ratio of the power imparted on the fluid by the pump in relation to the power supplied to drive the pump. Its value is not fixed for a given pump, efficiency is a function of the discharge and therefore also operating head. For centrifugal pumps, the efficiency tends to increase with flow rate up to a point midway through the operating range (peak efficiency or Best Efficiency Point (BEP) ) and then declines as flow rates rise further. Pump performance data such as this is usually supplied by the manufacturer before pump selection. Pump efficiencies tend to decline over time due to wear (e.g. increasing clearances as impellers reduce in size).

When a system includes a centrifugal pump, an important design issue is matching the *head loss-flow characteristic* with the pump so that it operates at or close to the point of its maximum efficiency.

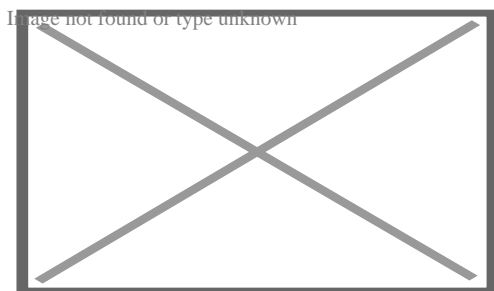
Pump efficiency is an important aspect and pumps should be regularly tested. Thermodynamic pump testing is one method.

### Minimum flow protection

[edit]

Most large pumps have a minimum flow requirement below which the pump may be damaged by overheating, impeller wear, vibration, seal failure, drive shaft damage or poor performance.<sup>[45]</sup> A minimum flow protection system ensures that the pump is not operated below the minimum flow rate. The system protects the pump even if it is shut-in or dead-headed, that is, if the discharge line is completely closed.<sup>[46]</sup>

The simplest minimum flow system is a pipe running from the pump discharge line back to the suction line. This line is fitted with an orifice plate sized to allow the pump minimum flow to pass.<sup>[47]</sup> The arrangement ensures that the minimum flow is maintained, although it is wasteful as it recycles fluid even when the flow through the pump exceeds the minimum flow.



Part of a process flow diagram of pump minimum flow protection arrangement

A more sophisticated, but more costly, system (see diagram) comprises a flow measuring device (FE) in the pump discharge which provides a signal into a flow controller (FIC) which actuates a flow control valve (FCV) in the recycle line. If the measured flow exceeds the minimum flow then the FCV is closed. If the measured flow falls below the minimum flow the FCV opens to maintain the minimum flowrate.<sup>[45]</sup>

As the fluids are recycled the kinetic energy of the pump increases the temperature of the fluid. For many pumps this added heat energy is dissipated through the pipework. However, for large industrial pumps, such as oil pipeline pumps, a recycle cooler is provided in the recycle line to cool the fluids to the normal suction temperature.<sup>[48]</sup> Alternatively the recycled fluids may be returned to upstream of the export cooler in an oil refinery, oil terminal, or offshore installation.

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## Machines

### Classical simple machines

### Clocks

### Compressors and pumps

### External combustion engines

### Internal combustion engines

### Linkages

### Turbine

### Aerofoil

- Inclined plane
- Lever
- Pulley
- Screw
- Wedge
- Wheel and axle
- Atomic clock
- Chronometer
- Pendulum clock
- Quartz clock
- Archimedes' screw
- Eductor-jet pump
- Hydraulic ram
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- Pantograph
- Peaucellier-Lipkin
- Gas turbine
- Jet engine
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- Water turbine
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- Sail
- Wing
- Rudder
- Flap
- Propeller

- Vacuum tube
- Transistor
- Diode
- Resistor
- Capacitor
- Inductor

- Automobile
- Mecha
- Robot

- Agricultural
- Seed-counting machine
- Vending machine
- Wind tunnel
- Check weighing machines
- Riveting machines
- Spring (device)

- Spring (device)

- Germany
- United States
- France

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- Japan
- Czech Republic
- Israel

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Driving Directions From 42.10843482977, -88.114090738222 to

Driving Directions From 42.086153671225, -88.19640031169 to

Driving Directions From 42.051159627372, -88.202951526236 to

Driving Directions From 42.008657936699, -88.152725208607 to

Driving Directions From 42.007242948498, -88.153060682778 to

Driving Directions From 42.073881347839, -88.179224443136 to

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