Put simply, head is the height at which a pump can raise fluid up and is measured in metres or feet. We use it when specifying centrifugal pumps because their pumping characteristics tend to be independent of the fluid’s specific gravity, often referred to as relative density. Manufacturers have many methods to fine tune or improve the performance of a centrifugal pump. Two of the most common are trimming the impeller and underfiling the discharge vanes. Impeller diameter chart Trimming can help achieve the rated or design point from a pull diameter by reducing capacity and head, which produces a lower capacity and head. Underfiling is used to improve or increase the head. Sometimes, underfiling is meant to correct an error from overtrimming or to increase head at full diameter. IMAGE 1: Illustration for reference points for trimming, or changing the speed of an impeller (Images courtesy of the author) Impeller Trim Pumps are each designed for a specific capacity and head. Since a pump cannot be designed for each operating condition required, compromises must be made. The most common of these is to trim the impeller. All impellers require a specified trim to achieve the flow and head required for the operating conditions. The trim may be full diameter, an extended diameter (if there is adequate clearance between the impeller and volute), or any size down to the minimum diameter of the impeller. Affinity Laws The affinity laws are one of the cornerstones of centrifugal pump performance and understanding them is paramount to understanding how a pump operates. The law is expressed in Equations 1, 2 and 3. These formulas are useful when calculating the head and capacity for variable speed application or for different diameters when the impeller is trimmed. The affinity laws indicate the influence on volume, capacity, head (pressure) and power consumption of a pump where a change in speed of the impeller (revolutions per minute [rpm]) or change in impeller diameter are involved. Note that both a change in diameter or speed have the same relationship to pump capacity. This is because a change in diameter alters the tip speed and the resulting centrifugal force of the impeller in the same way as a change in rpm, therefore producing the same results. Image 1 illustrates the effect of changing the speed or diameter of an impeller. Note that both the capacity and head change when the speed changes. The capacity by the ratio of the change in speed and head by the square of the change. Point 2 is generally referred to as the point where the new conditions will pull from, and Point 1 is the desired new operating condition. This would be the traditional impeller trim or reduction in diameter. In cases where the reference curve is smaller than the desired operating conditions, these references are reversed to obtain a larger diameter. This would describe a traditional impeller replacement from D2 where D1 > D2. Calculating the new diameter is a trial and error process and requires some “Kentucky Windage” (an adjustment to compensate for the circumstance). A point on the performance curve is selected where the new point will pull from (Point 2 in the illustration). Plug this value into the affinity equation and see where Q2, H2 plot on the curve. Repeat the process until Q2 and H2 plot on the reference curve. The formula used for the calculation is derived from combining Equation 1 and Equation 2. Once H1 is calculated and the point plots on the curve, the affinity trim ratio can be determined by the formula. In reality, the formula produces only an approximate result as it does not account for the loss of efficiency from moving the impeller away from its ideal position near the cutwater. The results are further corrected using a trim chart. IMAGE 2: Trim chart The Trim Chart The affinity laws are used for the initial trim selection and then the affinity diameter is corrected using the trim chart (Image 2). The trim chart produces a conservative value with the results skewed to the high side under the presumption that it is easier to trim the pump again than it is to add diameter back once it has been trimmed. If the trim chart diameter is greater than or equal to 97 percent of the reference trim diameter, round the corrected diameter up to the nearest 1/32 inch. If the trim chart diameter falls within 95 to 97 percent of the reference trim diameter, add 1/16 inch and round up to the nearest 1/32 inch. If the trim chart diameter falls below 95 percent of the reference trim diameter, add 3/32 inch to 1/8 inch and round up to the nearest 1/32 inch. For high suction speed (Ns), (> 2,000 US) pumps, apply the above rules and add an additional 1/16 inch to 3/32 inch. These corrections are just a guide; every pump is different, but it is easier to machine an oversize impeller than to put it back on. Instead of using the trim chart, the new diameter can be calculated using the slope intercept formula for the line. This formula can be expressed in Equation 6. When using the formula in Equation 6, round up to the same amounts as used with the trim chart. Changes in NPSH Changes in speed can also affect net positive suction head (NPSH). The new NPSH value can be obtained with the formula in Equation 7. A change in diameter has little effect on NPSH. For speed change up to 20 percent, NPSH can be calculated with the formula in Equation 87. If the speed changes by more than 20 percent, the formula is expressed in Equation 8. Note that the formula does not produce exact results. If the NPSH margin is critical, caution should be observed to ensure adequate NPSH results. Underfiling of Discharge Vanes Should the head fall below its requirement, small increases, usually around 1.5 percent to 2 percent, can be achieved by underfiling the discharge vanes. Underfiling involves thinning the blades from the back side to a thickness of about 1/8 inch and blending back into the impeller passage as far as practical to a achieve a smooth transition into the original hydraulic contour. IMAGE 3: Illustration of underfiling discharge vanes to increase the pump size IMAGE 4: Illustration of the increase in capacity and head resulting from underfiling the impeller discharge vanes There must be no perceivable humps in the transition as noted by running a finger along the hydraulics. Underfiling opens up the discharge area of the impeller, which increases the impeller capacity. By making the pump larger, the head also increases because the head capacity point at design is moved back on the new curve in respect to the best efficiency point (BEP). Typical length of metal removal is dependent on impeller size. The numbers presented in the "Impeller Diameter" chart can be used as a guide in determining how far the underfile must extend into the impeller. The right design point is important for good operation of the pump. An oversized pump must be throttled, resulting in wasted energy plus increased maintenance on the pump and control valve. An undersized pump will not produce the amount of product needed for the process. Using these methods will help the user fine tune the system for efficient operation. Moley Magnetics is the industry-leading magnetics manufacturer and lifting magnet supplier in North America. We offer a complete inventory of large industrial magnets, grapples, shears, and granulators to customers across various industries such as scrap, demolition, recycling, and distribution. Additionally, we sell and provide electric motor repair services in our Lockport, NY, headquarters, and custom motor fabrication services to clients nationwide. Moley sells and distributes a large selection of Electric Motors, Pumps, Generators, and related equipment for reputable brands, including Baldor, Leeson, Peerless, and Grundfos. Our team has the expertise to help identify the right equipment for any application whether its scrap, demolition, recycling, municipalities, agriculture, or food & beverage.View Electric Motors In addition to being a lifting magnet supplier, our team of master machinists and technicians can engineer solutions to meet your needs in our full-service repair shop. We are available 24/7 to repair Electric Motors, Pumps, Generators, Magnets and Grapples – as well as specialty services that can include Custom Fabrication, Gearboxes, Machining, Variable Frequency Drive Programming and Control Panel Building.View Service & Repair At Moley, we believe in the importance of educating our customers about our products. Explore our educational video series here and stay tuned as we expand our library.View Educational VideosWant to know more about our products or services? Contact Us How can financial brands set themselves apart through visual storytelling? Our experts explain how.Learn MoreThe Motorsport Images Collections captures events from 1895 to today’s most recent coverage.Discover The CollectionCurated, compelling, and worth your time. Explore our latest gallery of Editors’ Picks.Browse Editors' FavoritesHow can financial brands set themselves apart through visual storytelling? Our experts explain how.Learn MoreThe Motorsport Images Collections captures events from 1895 to today’s most recent coverage.Discover The CollectionCurated, compelling, and worth your time. Explore our latest gallery of Editors’ Picks.Browse Editors' FavoritesHow can financial brands set themselves apart through visual storytelling? Our experts explain how.Learn MoreThe Motorsport Images Collections captures events from 1895 to today’s most recent coverage.Discover The CollectionCurated, compelling, and worth your time. Explore our latest gallery of Editors’ Picks.Browse Editors' Favorites In fluids dynamics the term pump head is used to measure the kinetic energy which a pump creates. Head is a measurement of the height of the incompressible fluid column the pump could create from the kinetic energy, that the pump gives to the liquid. The head and flow rate determine the performance of a pump, which is graphically shown in the figure as the performance curve or pump characteristic curve. The main reason for using head instead of pressure to determine the performance of a centrifugal pump is that the height of the fluid column is not dependent on the specific gravity (weight) of the liquid, while the pressure from a pump will change. In terms of pressure the pump head (ΔPpump) is difference between system back pressure and the inlet pressure of the pump.The maximum pump head of a centrifugal pump is mainly determined by the outside diameter of the pump’s impeller and the shaft angular velocity – speed of the rotating shaft. The head will also change as the volumetric flow rate through the pump is increased.When a centrifugal pump is operating at a constant angular velocity, an increase in the system head (back pressure) on the flowing stream causes a reduction in the volumetric flow rate that the centrifugal pump can maintain.The relationship between the pump head and the volumetric flow rate (Q), that a centrifugal pump can maintain, is dependent on various physical characteristics of the pump as:the power supplied to the pumpthe angular velocity of shaftthe type and diameter of the impellerand the used fluid:fluid densityfluid viscosityThis relationship is very complicated and its analysis lies in extensive hydraulic testing of certain centrifugal pump. As can be seen from the picture below.We hope, this article, Pump Head – Performance Curve of Centrifugal Pump, helps you. If so, give us a like in the sidebar. Main purpose of this website is to help the public to learn some interesting and important information about thermal engineering. Centrifugal pumps are one of the most common components found in fluid systems. In order to understand how a fluid system containing a centrifugal pump operates, it is necessary to understand the head and flow relationships for a centrifugal pump. Energy Conversion in a Centrifugal Pump Fluid entering a centrifugal pump is immediately directed to the low pressure area at the center or eye of the impeller. As the impeller and blading rotate, they transfer momentum to incoming fluid. A transfer of momentum to the moving fluid increases the fluid's velocity. As the fluid's velocity increases its kinetic energy increases. Fluid of high kinetic energy is forced out of the impeller area and enters the volute. The volute is a region of continuously increasing cross-sectional area designed to convert the kinetic energy of the fluid into fluid pressure. The mechanism of this energy conversion is the same as that for subsonic flow through the diverging section of a nozzle. The mathematical analysis of flow through the volute is based on the general energy equation, the continuity equation, and the equation relating the internal properties of a system. The key parameters influencing the energy conversion are the expanding cross-sectional area of the volute, the higher system back pressure at the discharge of the volute, and the incompressible, subsonic flow of the fluid. As a result of the interdependence of these parameters, the fluid flow in the volute, similar to subsonic flow in a diverging nozzle, experiences a velocity decrease and a pressure increase. Operating Characteristics of a Centrifugal Pump Normally, a centrifugal pump produces a relatively low pressure increase in the fluid. This pressure increase can be anywhere from several dozen to several hundred psid across a centrifugal pump with a single stage impeller. The term PSID (Pounds Force Per Square Inch Differential) is equivalent to ΔP. In this context, it is the pressure difference between the suction and discharge of a pump. PSID can also be used to describe a pressure drop across a system component (strainers, filters, heat exchangers, valves, demineralizers, etc.). When a centrifugal pump is operating at a constant speed, an increase in the system back pressure on the flowing stream causes a reduction in the magnitude of volumetric flow rate that the centrifugal pump can maintain. Analysis of the relationship between the volumetric flow rate (\(\dot{V} \)) that a centrifugal pump can maintain and the pressure differential across the pump (ΔPpump) is based on various physical characteristics of the pump and the system fluid. Variables evaluated by design engineers to determine this relationship include the pump efficiency, the power supplied to the pump, the rotational speed, the diameter of the impeller and blading, the fluid density, and the fluid viscosity. The result of this complicated analysis for a typical centrifugal pump operating at one particular speed is illustrated by the graph in Figure 7. Figure 7: Typical Centrifugal Pump Characteristic Curve Pump head, on the vertical axis, is the difference between system back pressure and the inlet pressure of the pump (ΔPpump). Volumetric flow rate (\(\dot{V} \)), on the horizontal axis, is the rate at which fluid is flowing through the pump. The graph assumes one particular speed (N) for the pump impeller. Cavitation When the liquid being pumped enters the eye of a centrifugal pump, the pressure is significantly reduced. The greater the flow velocity through the pump the greater this pressure drop. If the pressure drop is great enough, or if the temperature of the liquid is high enough, the pressure drop may be sufficient to cause the liquid to flash to steam when the local pressure falls below the saturation pressure for the fluid that is being pumped. These vapor bubbles are swept along the pump impeller with the fluid. As the flow velocity decreases the fluid pressure increases. This causes the vapor bubbles to suddenly collapse on the outer portions of the impeller. The formation of these vapor bubbles and their subsequent collapse is cavitation. Cavitation can be a very serious problem for centrifugal pumps. Some pumps can be designed to operate with limited amounts of cavitation. Most centrifugal pumps cannot withstand cavitation for significant periods of time; they are damaged by erosion of the impeller, vibration, or some other cavitation-induced problem. Net Positive Suction Head It is possible to ensure that cavitation is avoided during pump operation by monitoring the net positive suction head of the pump. Net positive suction head (NPSH) for a pump is the difference between the suction pressure and the saturation pressure of the fluid being pumped. NPSH is used to measure how close a fluid is to saturated conditions. Equation 3-19 can be used to calculate the net positive suction head available for a pump. The units of NPSH are feet of water. NPSH = Psuction − Psaturation where: Psuction = suction pressure of the pump Psaturation = saturation pressure for the fluid By maintaining the available NPSH at a level greater than the NPSH required by the pump manufacturer, cavitation can be avoided. PDH Classroom offers a continuing education course based on this centrifugal pumps reference page. This course can be used to fulfill PDH credit requirements for maintaining your PE license. Now that you've read this reference page, earn credit for it! Pump Laws Centrifugal pumps generally obey what are known as the pump laws. These laws state that the flow rate or capacity is directly proportional to the pump speed; the discharge head is directly proportional to the square of the pump speed; and the power required by the pump motor is directly proportional to the cube of the pump speed. These laws are summarized in the following equations. $$ \dot{V} \propto n $$ $$ H_p \propto n^2 $$ $$ P \propto n^3 $$ where: n = speed of pump impeller (rpm) \(\dot{V} \) = volumetric flow rate of pump (gpm or ft3/hr) Hp = head developed by pump (psid or feet) P = pump power (kW) Using these proportionalities, it is possible to develop equations relating the condition at one speed to those at a different speed. $$ \dot{V}_1 \left({n_2 \over n_1}\right) = \dot{V}_2 $$ $$ H_{p.1} \left({n_2 \over n_1}\right)^2 = H_{p.2} $$ $$ P_1 \left({n_2 \over n_1}\right)^3 = P_2 $$ Example: Pump Laws A cooling water pump is operating at a speed of 1800 rpm. Its flow rate is 400 gpm at a head of 48 ft. The power of the pump is 45 kW. Determine the pump flow rate, head, and power requirements if the pump speed is increased to 3600 rpm. Solution: Flow rate $$ \begin{eqnarray} \dot{V}_2 &=& \dot{V}_1 \left({n_2 \over n_1}\right) onumber \\ &=& (400 ~\text{gpm}) \left({ 3600 ~\text{rpm} \over 1800 ~\text{rpm} }\right) onumber \\ &=& 800 ~\text{gpm} \end{eqnarray} $$ Head $$ \begin{eqnarray} H_{p.2} &=& H_{p.1} \left({n_2 \over n_1}\right)^2 onumber \\ &=& 48 ~\text{ft} \left({ 3600 ~\text{rpm} \over 1800 ~\text{rpm} }\right)^2 onumber \\ &=& 192 ~\text{ft} \end{eqnarray} $$ Power $$ \begin{eqnarray} P_2 &=& P_1 \left({n_2 \over n_1}\right)^3 onumber \\ &=& 45 ~\text{kW} \left({ 3600 ~\text{rpm} \over 1800 ~\text{rpm} }\right)^3 onumber \\ &=& 360 ~\text{kW} \end{eqnarray} $$ It is possible to develop the characteristic curve for the new speed of a pump based on the curve for its original speed. The technique is to take several points on the original curve and apply the pump laws to determine the new head and flow at the new speed. The pump head versus flow rate curve that results from a change in pump speed is graphically illustrated in Figure 8. Figure 8: Changing Speeds for Centrifugal Pump In the chapter on head loss, it was determined that both frictional losses and minor losses in piping systems were proportional to the square of the flow velocity. Since flow velocity is directly proportional to the volumetric flow rate, the system head loss must be directly proportional to the square of the volumetric flow rate. From this relationship, it is possible to develop a curve of system head loss versus volumetric flow rate. The head loss curve for a typical piping system is in the shape of a parabola as shown in Figure 9. Figure 9: Typical System Head Loss Curve The point at which a pump operates in a given piping system depends on the flow rate and head loss of that system. For a given system, volumetric flow rate is compared to system head loss on a system characteristic curve. By graphing a system characteristic curve and the pump characteristic curve on the same coordinate system, the point at which the pump must operate is identified. For example, in Figure 10, the operating point for the centrifugal pump in the original system is designated by the intersection of the pump curve and the system curve (hLo). Figure 10: Operating Point for a Centrifugal Pump The system has a flow rate equal to \(\dot{V}_o \) and a total system head loss equal to ΔPo. In order to maintain the flow rate (\(\dot{V}_o \)), the pump head must be equal to ΔPo. In the system described by the system curve (hL1), a valve has been opened in the system to reduce the system's resistance to flow. For this system, the pump maintains a large flow rate (\(\dot{V}_1 \)) at a smaller pump head (ΔP1). System Use of Multiple Centrifugal Pumps A typical centrifugal pump has a relatively low number of moving parts and can be easily adapted to a variety of prime movers. These prime movers include AC and DC electric motors, diesel engines, steam turbines, and air motors. Centrifugal pumps are typically small in size and can usually be built for a relatively low cost. In addition, centrifugal pumps provide a high volumetric flow rate with a relatively low pressure. In order to increase the volumetric flow rate in a system or to compensate for large flow resistances, centrifugal pumps are often used in parallel or in series. Figure 11 depicts two identical centrifugal pumps operating at the same speed in parallel. Figure 11: Pump Characteristic Curve for Two Identical Centrifugal Pumps Used in Parallel Centrifugal Pumps in Parallel Since the inlet and the outlet of each pump shown in Figure 11 are at identical points in the system, each pump must produce the same pump head. The total flow rate in the system, however, is the sum of the individual flow rates for each pump. When the system characteristic curve is considered with the curve for pumps in parallel, the operating point at the intersection of the two curves represents a higher volumetric flow rate than for a single pump and a greater system head loss. As shown in Figure 12, a greater system head loss occurs with the increased fluid velocity resulting from the increased volumetric flow rate. Because of the greater system head, the volumetric flow rate is actually less than twice the flow rate achieved by using a single pump. Figure 12: Operating Point for Two Parallel Centrifugal Pumps Centrifugal Pumps in Series Centrifugal pumps are used in series to overcome a larger system head loss than one pump can compensate for individually. As illustrated in Figure 13, two identical centrifugal pumps operating at the same speed with the same volumetric flow rate contribute the same pump head. Since the inlet to the second pump is the outlet of the first pump, the head produced by both pumps is the sum of the individual heads. The volumetric flow rate from the inlet of the first pump to the outlet of the second remains the same. Figure 13: Pump Characteristic Curve for Two Identical Centrifugal Pumps Used in Series As shown in Figure 14, using two pumps in series does not actually double the resistance to flow in the system. The two pumps provide adequate pump head for the new system and also maintain a slightly higher volumetric flow rate. Figure 14: Operating Point for Two Centrifugal Pumps in Series PDH Classroom offers a continuing education course based on this centrifugal pumps reference page. This course can be used to fulfill PDH credit requirements for maintaining your PE license. Now that you've read this reference page, earn credit for it! Almost every cleaning system incorporates at least one pump. Understanding how that pump works and how to treat it with the gentle, loving care it deserves is critical to the successful operation and maintenance of a cleaning system. Pumps are, in general, devices which impart added pressure to a flow of liquid. Although there are a number of different kinds of pumps, centrifugal pumps make up the overwhelming majority of those used in cleaning systems. Centrifugal pumps are simple, efficient, reliable, relatively inexpensive, and easily meet the needs of most cleaning system requirements including spraying, overflow sparging, filtration, turbulation and just moving liquids from one place to another using pressure. A centrifugal pump uses a combination of angular velocity and centrifugal force to pump liquids. The illustration below describes, generally, how a centrifugal pump works. The pump consists of a circular pump housing shaped somewhat like a donut with an inlet where the donut hole would be. The outlet extends tangentially from the diameter of the pump housing. Inside the pump housing there is a device called an “impeller” which rotates perpendicular to the central axis of the pump housing and is driven by a shaft secured to its center of rotation. The shaft, frequently powered by an integral electric motor, enters the pump housing through a liquid tight seal which prevents leaking. Liquid entering the pump through the inlet is swirled in a circular motion and displaced from the rotation center of the impeller by centrifugal force. The combination of the swirling action (angular velocity) and centrifugal force (radial velocity) push the liquid being pumped out of the pump through the outlet. Things to Know About Centrifugal Pumps – Centrifugal pumps are relatively maintenance-free except for the seal on the rotating shaft. These seals need to be replaced on a regular basis. The material of construction of the pump and the pump seal need to be selected based on the liquid being pumped. Liquids containing abrasives (particles shed from grinding wheels and lapping compound for example) often require special consideration for the seal to prevent premature wear. In extreme cases, a secondary supply of abrasive-free liquid is supplied directly to the wear surfaces of the seal. Pump seals must be kept lubricated and cooled. Both lubrication and cooling are normally provided by the liquid being pumped. Because of this, centrifugal pumps should not be operated without liquid being present in the pump. Failure of the pump seal due to overheating as a result of friction may happen in less than a minute of operation without liquid in the pump. Centrifugal pumps must have a “flooded inlet” when liquid pumping starts. In simple terms, liquid should arrive at the inlet of the pump as a result of gravity. The pump, which has relatively large clearances between the impeller and the pump body, will not provide a vacuum to lift liquid against the force of gravity. In some instances, once the pump is “primed” with liquid, it can work against the force of gravity. “Priming” is accomplished by filling the pump and the plumbing leading to the pump with liquid prior to turning it on. Operation in this mode is not encouraged as the “priming” step is often overlooked. The impeller in a centrifugal pump MUST rotate in the correct direction. In pumps operating from a single phase electrical source, this is not a problem. In pumps operating from a three phase electrical source, however, the proper phasing sequence of the three wires supplying power to the pump must be correct. If any two wires are reversed, the three phase motor will rotate in the reverse direction. Most centrifugal pumps have an arrow indicating the proper rotation direction located either on the pump body or on the motor. If the pump motor rotates in the direction opposite that indicated on the pump, reverse any two wires in the supply to change the direction of rotation. The basic centrifugal pump described above takes on many different configurations depending on its intended use. Further description of these variations of the centrifugal pump as well as other types of pumps will be provided in upcoming blogs. – FJF – Pumps can be arranged and connected in serial or parallel to provide additional head or flow rate capacity. Pumps in Serial - Head Added When two (or more) pumps are arranged in serial their resulting pump performance curve is obtained by adding their heads at the same flow rate as indicated in the figure below. Centrifugal pumps in series are used to overcome larger system head loss than one pump can handle alone. for two identical pumps in series the head will be twice the head of a single pump at the same flow rate - as indicated with point 2. With a constant flowrate the combined head moves from 1 to 2 - BUT in practice the combined head and flow rate moves along the system curve to point 3. point 3 is where the system operates with both pumps running point 1 is where the system operates with one pump running Note that for two pumps with equal performance curves running in series the head for each pump equals half the head at point 3 the flow for each pump equals the flow at point 3 Operation of single stage pumps in series are seldom encountered - more often multistage centrifugal pumps are used. Pumps in Parallel - Flow Rate Added When two or more pumps are arranged in parallel their resulting performance curve is obtained by adding the pumps flow rates at the same head as indicated in the figure below. Centrifugal pumps in parallel are used to overcome larger volume flows than one pump can handle alone. for two identical pumps in parallel and the head kept constant - the flow rate doubles compared to a single pump as indicated with point 2 Note! In practice the combined head and volume flow moves along the system curve as indicated from 1 to 3. point 3 is where the system operates with both pumps running point 1 is where the system operates with one pump running In practice, if one of the pumps in parallel or series stops, the operation point moves along the system resistance curve from point 3 to point 1 - the head and flow rate are decreased. Note that for two pumps with equal performance curves running in parallel the head for each pump equals the head at point 3 the flow for each pump equals half the flow at point 3 Note - for parallel operation zero flow or “shut valve” heads must match for the pumps unstable pump curves must be avoided steeper pump curves are preferred Securing a system and achieve equal wear by alternating pumps in parallel. An introduction to Centrifugal Pumps. Introduction tutorial to positive displacement pumps basic operating principles. Calculate pressure loss in pipes connected in series or parallel. Calculate the energy cost of pumping water. Horsepower required to pump water. Static pressure vs. pressure head in fluids. Utilize the system curve and the pump performance curve to select the proper pump for a particular application. Centrifugal pumps are one of the most common types of pumps used in a variety of industries including oil refineries, power plants, and municipalities; but how do they work? We’re glad you asked. After reading the following guide, you’ll understand how centrifugal pumps work; read on to learn more.Some experts debate about when the first centrifugal pump was invented. Most arguments say the Frenchman, Denis Papin, invented the first straight-vane centrifugal pump in the late 1600s. John Appold of Great Britain invented the first curved-vane centrifugal pump in 1851. Centrifugal pumps are primarily for transporting liquids with rotational energy (more on that next). You should note that centrifugal pumps perform best with low-viscosity fluids.The foundation of a centrifugal pump is its impeller. As the fluid enters the pump, the fluid will pass through the eye of the impeller and exit through the impeller’s vanes. With the aid of the rotating impeller, the fluid will discharge from the pump’s casing at a controlled pressure. The pressure is controlled by both the electric motor and kinetic energy. You should note that most centrifugal pumps come with one of two casing designs: volute and diffuser. Both designs provide release of the fluid at a consistent pressure, but they do so differently. The main factor to note is that a volute casing has an offset impeller which produces a curved cone that pushes the fluid toward the outlet. Alternatively, a diffuser casing has motionless vanes around the impeller which is an easier design to manipulate for specific applications.As you can see, understanding how centrifugal pumps work is surprisingly simple. In essence, you have a fluid input and the impeller pushes the fluid through as the output. What’s not as simple is repairing these pumps. If you don’t know what you’re doing, you’re going to waste a lot of time and potentially damage the pump.If you’re searching for a reputable industrial pump supply company, you’ve come to the right place. Moley Magnetics is a premier supplier for industrial pumps, but we don’t stop there. Our team consists of industry experts who also know how to perform a number of repairs to get your pump back up and running in no time. If you’d like to request pricing or have any questions at all, don’t hesitate to reach out to us today. Manufacturers have many methods to fine tune or improve the performance of a centrifugal pump. Two of the most common are trimming the impeller and underfiling the discharge vanes. Impeller diameter chart Trimming can help achieve the rated or design point from a pull diameter by reducing capacity and head, which produces a lower capacity and head. Underfiling is used to improve or increase the head. Sometimes, underfiling is meant to correct an error from overtrimming or to increase head at full diameter. IMAGE 1: Illustration for reference points for trimming, or changing the speed of an impeller (Images courtesy of the author) Impeller Trim Pumps are each designed for a specific capacity and head. Since a pump cannot be designed for each operating condition required, compromises must be made. The most common of these is to trim the impeller. All impellers require a specified trim to achieve the flow and head required for the operating conditions. The trim may be full diameter, an extended diameter (if there is adequate clearance between the impeller and volute), or any size down to the minimum diameter of the impeller. Affinity Laws The affinity laws are one of the cornerstones of centrifugal pump performance and understanding them is paramount to understanding how a pump operates. The law is expressed in Equations 1, 2 and 3. These formulas are useful when calculating the head and capacity for variable speed application or for different diameters when the impeller is trimmed. The affinity laws indicate the influence on volume, capacity, head (pressure) and power consumption of a pump where a change in speed of the impeller (revolutions per minute [rpm]) or change in impeller diameter are involved. Note that both a change in diameter or speed have the same relationship to pump capacity. This is because a change in diameter alters the tip speed and the resulting centrifugal force of the impeller in the same way as a change in rpm, therefore producing the same results. Image 1 illustrates the effect of changing the speed or diameter of an impeller. Note that both the capacity and head change when the speed changes. The capacity by the ratio of the change in speed and head by the square of the change. Point 2 is generally referred to as the point where the new conditions will pull from, and Point 1 is the desired new operating condition. This would be the traditional impeller trim or reduction in diameter. In cases where the reference curve is smaller than the desired operating conditions, these references are reversed to obtain a larger diameter. This would describe a traditional impeller replacement from D2 where D1 > D2. Calculating the new diameter is a trial and error process and requires some “Kentucky Windage” (an adjustment to compensate for the circumstance). A point on the performance curve is selected where the new point will pull from (Point 2 in the illustration). Plug this value into the affinity equation and see where Q2, H2 plot on the curve. Repeat the process until Q2 and H2 plot on the reference curve. The formula used for the calculation is derived from combining Equation 1 and Equation 2. Once H1 is calculated and the point plots on the curve, the affinity trim ratio can be determined by the formula. In reality, the formula produces only an approximate result as it does not account for the loss of efficiency from moving the impeller away from its ideal position near the cutwater. The results are further corrected using a trim chart. IMAGE 2: Trim chart The Trim Chart The affinity laws are used for the initial trim selection and then the affinity diameter is corrected using the trim chart (Image 2). The trim chart produces a conservative value with the results skewed to the high side under the presumption that it is easier to trim the pump again than it is to add diameter back once it has been trimmed. If the trim chart diameter is greater than or equal to 97 percent of the reference trim diameter, round the corrected diameter up to the nearest 1/32 inch. If the trim chart diameter falls within 95 to 97 percent of the reference trim diameter, add 1/16 inch and round up to the nearest 1/32 inch. If the trim chart diameter falls below 95 percent of the reference trim diameter, add 3/32 inch to 1/8 inch and round up to the nearest 1/32 inch. For high suction speed (Ns), (> 2,000 US) pumps, apply the above rules and add an additional 1/16 inch to 3/32 inch. These corrections are just a guide; every pump is different, but it is easier to machine an oversize impeller than to put it back on. Instead of using the trim chart, the new diameter can be calculated using the slope intercept formula for the line. This formula can be expressed in Equation 6. When using the formula in Equation 6, round up to the same amounts as used with the trim chart. Changes in NPSH Changes in speed can also affect net positive suction head (NPSH). The new NPSH value can be obtained with the formula in Equation 7. A change in diameter has little effect on NPSH. For speed change up to 20 percent, NPSH can be calculated with the formula in Equation 87. If the speed changes by more than 20 percent, the formula is expressed in Equation 8. Note that the formula does not produce exact results. If the NPSH margin is critical, caution should be observed to ensure adequate NPSH results. Underfiling of Discharge Vanes Should the head fall below its requirement, small increases, usually around 1.5 percent to 2 percent, can be achieved by underfiling the discharge vanes. Underfiling involves thinning the blades from the back side to a thickness of about 1/8 inch and blending back into the impeller passage as far as practical to a achieve a smooth transition into the original hydraulic contour. IMAGE 3: Illustration of underfiling discharge vanes to increase the pump size IMAGE 4: Illustration of the increase in capacity and head resulting from underfiling the impeller discharge vanes There must be no perceivable humps in the transition as noted by running a finger along the hydraulics. Underfiling opens up the discharge area of the impeller, which increases the impeller capacity. By making the pump larger, the head also increases because the head capacity point at design is moved back on the new curve in respect to the best efficiency point (BEP). Typical length of metal removal is dependent on impeller size. The numbers presented in the "Impeller Diameter" chart can be used as a guide in determining how far the underfile must extend into the impeller. The right design point is important for good operation of the pump. An oversized pump must be throttled, resulting in wasted energy plus increased maintenance on the pump and control valve. An undersized pump will not produce the amount of product needed for the process. Using these methods will help the user fine tune the system for efficient operation. We're going to be looking at pump calculations and, specifically, we're going to be looking at how to calculate the Flow Rate Pump RPMHead PressurePump PowerImpeller DiameterIf you already have a pump installed in one of your buildings, then you should have a checklist or a sheet that comes which is the datasheet for that pump. All too often, parts of this design data are missing and that's frustrating. But if you have some data missing then we're going to look at some formulas of how to calculate and fill in these gaps, and also, we'll look to see what would happen if you were to change some of these parameters.Also Read: How to Calculate Cooling Capacity of a Chiller in HVAC If you haven't got the pump installed yet, you're in a design phase, and then you can also use these formulas to determine what the performance will be. Remember that these calculations will only give us theoretical values. The actual performance may vary from these. And, you know, certainly, the old a pump gets, the larger the discrepancy becomes between the theoretical and the actual answer. You might need to add on a correction factor to adjust these. Now we jump into the calculations Flow Rate (Increase/Decrease RPM)Here we are going to find what would be the new flow rate if we were to increase or decrease the pump revolutions per minute. So the next one we're going to look at is the new flow rate, and that would occur if you were to change the impeller diameter. Now, I will point out that this is an older way to do, to trim down the impeller to change its diameter. It's not the preferred way anymore, and that's because if you, once you trim it down, you can't, obviously, add that material back on. So you need to replace the entire impeller. A much better way is to actually use a variable speed drive or variable frequency drive to change the speed of the pump to meet your design criteria. But if you are looking to change the impeller or to even trim the impeller down, then you can use these calculations here.Also Read: How to Calculate Chiller Efficiency in HVAC Pump RPM (Increase/Decrease Flow Rate)So that is the speed that the impeller needs to rotate at in order to achieve this new flow rate. So the next one we'll look at is how to calculate the head pressure, and this would occur if you were to increase or decrease the revolutions per minute of the impeller. The next one we'll look at is also head pressure, and that will be how to calculate this should you increase or decrease the flow rate. So the next one is the pump power, how to calculate it? What the new pump power would be? Should you increase or decrease the revolutions per minute of the pump? Impeller DiameterAnd then, last one we're going to look at is the impeller diameter. So if you were to adjust the flow rate and you wanted to achieve this new flow rate, what diameter impeller would you need? And this is usually used in the case where the impeller is being trimmed down to meet a new flow rate. If you have any questions, please leave them in the comments section below. Centrifugal pumps rely on fluid to keep cool and lubricated while operating. They also rely on the fact that discharged fluid has somewhere to go. But what if the process dictates it needs only a fraction of the pump’s minimum flow requirement? What if there's a closed valve downstream? What happens when a pump’s basic hydraulic needs are no longer met? This is where a minimum flow bypass line is best applied. A bypass line is most commonly used when there’s an issue meeting the minimum flow requirements, and/or for protection against deadheading the pump. A minimum flow bypass, or recirculation, line can be configured many ways. It could be as simple as a continuous bypass, where the requirements are only piping and an orifice. A more complex line could be set up to use a series of valves. Below is an illustration of a simple minimum flow bypass line. Meeting Minimum Flow Conditions Every pump has a minimum flow requirement. Operating pumps at below minimum flow can result in the following consequences: Pitted/worn impeller vanes Overheated casing/bearings Excessive noise or vibration Broken shafts Mechanical seal failures Poor performance efficiency Adding a bypass line will allow the pump to sustain the minimum flow requirement, even when the process requires less flow. Protection Against Deadheading Our Application Engineers always recommend installing a recirculation line when high pressure pumps are in use. If a high pressure pump is deadheaded, significant damage results for the pump or the system. Not only can this be an expensive mistake, but also a cause for safety concern. Recirculation lines provide a means of relief for high pressure pumps when operated against a closed valve or other system obstruction. Process Liquid Impact Consideration Meeting minimum flow and protecting the pump against deadheading conditions are the main reasons why recirculation loops are installed. But, they can also help keep product in a desired state. For instance, they can help turn a tank over and keep solids in suspension. They can also keep fluids susceptible to change, due to temperature or shear thinning/thickening, in the state preferred for process. Some engineers have concerns about the inevitable wasted energy that comes from using minimum flow bypass lines. It’s important that the system has been evaluated to ensure the pump is properly sized for the application and the bypass line is absolutely necessary. If you’re not sure that a bypass line is right for you, consult an engineer who is well versed in pump selection and pipe design. Need help with a tough pumping application? Ask us about it! We gladly provide technical assistance to businesses and municipalities in Wisconsin and upper Michigan. Skip to main navigationSkip to main contentSkip to footer Efficient and environmentally sound solutions for challenging parts cleaning applications.September 29 - October 1, 2025Las Vegas, NVBooth N-5968View all Events Share — copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt — remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution — You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation . No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. You can probably increase the impeller size in the pump. Ask the manufacturer for pump curves for larger impellers, and that will tell you flow at TDH. Impellers are usually cheaper than a new motor. You need to decrease the pressure drop through your piping or produce more head from your pump. Reducing the dP likely means increasing your discharging piping size (pressure drop is proportional to the ratio of the diameters to the 5th power). Is the installed impeller in the pump the maximum? A larger impeller will give you more head, that might drive you to the next sized motor, starter, etc. You can also look whether you can reduce the flow rate but I doubt that's a feasible solution. Other options. Can you lower the delivery pressure or increase the supply pressure? If you have a control valve, does resizing the control valve to a larger trim get you enough additional pressure drop (my experience would say no but I'll throw them out as an option to consider). A 10 hP motor isn't very expensive. In terms of cost, replacing the impeller is likely the least expensive option as pointed out by Roach. Upsizing the pipe, if it’s relatively short (and isn’t installed) might be another option. If the piping is relatively long, replacing the entire pump will the least expensive solution. Generally when a pump is ordered it is powered thru it's curve meaning that for the impellor size no matter what the pressure or flow (since they are related) the pump will not overload. Increasing the hp without changing the impellor will not do anything. If you change the impellor more than likely you will exceed the hp power curve but depending where you are on the curve you maybe within the hp rating (generally 1.15 service factor on the motor). If you have a relief valve it can protect the motor and system. In small pump system like this it may be cheaper to just buy a new pump, it is much easier than ordering a impeller or changing out a motor (motor and pump alignment are very important). I usually don't see impellor changeouts unless the pump is special or 25 hp and above. You can underfile the edges of the impeller vanes. This will get you up to 3% more head. PMPVIVGUY Can you please explain the procedure for underfiling? Underfiling is beveling the suction side trailing edges of the impeller blades (concave blade side with backward curved blades. This changes the discharge angle slightly, increasing the head. It should be a controlled process applied to every blade and requires shaving or filing away the metal. Overfiling, done to the pressure side of the blade trailing edges (convex side) has the opposite effect and reduces head. for a given pump you could increase rpm and the suite the new motor. Check for the nominal current at name plate, read with a amprobe wath curren are you runig yet , maybe you will not need to change motor. Pardal Also buying a cheap inverter and ramping up your Hz is an option Increasing motor size will do absolutly nothing,assuming you have a maximum diameter impeller. Underfiling (also called backfiling) will only give you short term head increases and is therefore only a short term fix. Pump companies will sometimes do that to the new impeller to help it pass it's performance test especially when using HI "A" criteria. Underfiling makes the vanes very sharp - almost like a knife edge. But like everything in life, nothing is free. As the pump operates, you will notice that the head will drop back to what it "should" be as the vanes become more dull. You could put a 100hp motor on the pump and still get no more out of it if you don't change the impeller. A 10hp motor shouldn't cost you but a couple hundred dollars or so - depending on the specs. So, what's cheaper? Changing the pipe to a larger size or purchasing a totally new pump? Given that it's a 7.5hp pump, I would venture a guess to say that buying a new pump will be cheaper. Like other people suggestes, at the least, you should consider a larger impeller if possible. You would have to pay for a new impeller, a new motor, and probably a few gaskets. Don't forget the labor to take the pump apart, remove the old impeller, put the new impeller one, and put the pump back together. You're probably looking at around $800 to do all of that. Tim S. To tstead Underfiling is not a temporary fix for any impeller to which it is applied. The removed metal is gone forever and the associated flow discharge angle change that raises pump head will last as long as the impeller. Underfiling may be a "temporary fix" to the first of many impellers of the same design to be manufactured because it involves more work and should , for the sake of manufacturing costs, be replaced by an alternate solution. If the impeller diameter is oversized , as is usually done to assure head requirments are met. then the best alternate solution to underfiling is to increase the final maching outside diameter to get the required head without underfiling. What caused the pressure drop, a larger pipe will give you less friction loss, thus increasing pump head. Either the pump was sized wrong, it is out of ajustment (semi-open impeller) or it is worn out at the seal ring (enclosed) Backfiling will increase eff. However it is probably allready backfiled and there is noway to say it is going to increase a fixed amount, every impeller has different backfile results. Contact your pump supplier and they can recommend the best remidy for your problem. Let them know your suction pressure, current pump design, pipe size and lenght,elbows,and required discharge pressure. This wont cost a dime and you will know exactly what you will have to do. More head...hmmm. You didn't say what you were pumping (abrasive, water, etc.), so I'll take a shot at it. Put a new suction liner in it. New liners will decrease the distance between the impeller and liner. That will help with the head AND the efficiency. Next would be an increase of impeller trim....or a new trimmed impeller. As I mentioned, there's not much info to go on, so my suggestions is a general fix. More info will get better results. Jack It seems to be a very very useful Forum. I got lot of doubts in fluid engineering. I understand that pressure drop is directly proportional to the ratio of diameters to the fifth power. Can you explain it by giving any examples. The easiest way of showing it Peninsula is to do some hydraulic line loss calculations and confirm it for yourself. Essentially, let's say you have a 4" sch 40 line and you are considering whether to replace it with a 6" sch 40 line. The ratio of the IDs to the 5th power is (4.026/6.065)^5 = 0.129. So, the pressure drop through a 6" line is about 13% of that of a 4" line. It's not an exact number as other factors come into the pressure drop but it's pretty good for an estimate. This is true for incompressible fluids for virtually any dP (until you start flashing). For gases, it's valid for pressure drops that don't exceed about 10% of the inlet pressure. No one has yet suggested that you might want to model your piping system and see what the pressure drop shold be theoretically. You may 1)have pipe that has built up deposits on the ID of the pipe thus decreasing its effective diameter for flow, or 2) someone has perhaps modified the pipe system, or 3) someone may have installed a resticting orifice plate for pressure drop or flow measurement, or 4) perhaps there is a plugged screen, or a broken valve stem or etc etc. Point is make sure there is not a greater problem facing you before you decide to change the pump; because a larger impeller can also create a problem if not matched to the system its in. The more you learn, the less you are certain of. Interesting thread. I had heard of trimming the impeller to decrease performance in an oversized pump, but never the opposite. You learn something new every day. Here is one thought that is kind of a longshot. Regarding changing the motor... there is some limited capability for gaining pump performance if you can reduce the slip. Some older and smaller motors may have 2% slip or more. Take a look at your nameplate RPM to get an idea of how much you can gain by buying a motor which operates closer to syncronous speed. Newer motors designed for high efficiency typically have much lower rotor resistance which results in much lower nameplate slip. If you can increase your speed by 1% that is of course 1% flow and 2% head increase. As was mentioned before, changing motors on this small a machine might be more trouble than it's worth (compared to cost of new pump/motor combination). Thank you very much for your reply. can you explain what will be the calculation pipe contraction.Iam preparing my machine schematic digram .thatwill help you to advise me. Brattong: Your actual operation is not known. The VFD idea could fix your problem, but if your motor is close to 100% load you won't increase the speed with a VFD. Remember the HP required increases at the cube of the speed change for centrifugal loads while the head only increases at the square. One thing I would consider is the possibility of increasing the intake pressure if possible. Pressure is additive. David I have briefly looked at the responses thus far, so apologize if I am repeating something previously stated. Buying a new motor for a centrifugal pump will probably not incraewse the discharge head 15 ft. Your motor unless it is severly undersized should be run not too far from the nominal operating speed. Check the amps to make sure your under the full load amps (FLA) at you operating point. Under filing will get you about a 3% head increase if it hasn't already been done at the factory. The only true way to increase your discharge head is to increade the pump speed or increase the impeller diameter. Buy purchasing a VFD you can greatly increase the control of your flow and head output often while reducing your energy consumption (costs). When purchasing a new pump it is always a wise idea to purchase a pump with an impeller that is 80% of the full diameter impeller. This gives you room to grow or overcome sizing mistakes made during selection. You may wish to make an inspection or your current impeller to make sure it is not eroded or damaged. Greg Case MechTronix Engineering Turbomachinery Consultants Hey To increase the head of the pump you have increase the diameter of impeller not the motor. Usually to increase the discharge reduce the diameter and to increase the head increase the diameter of the impeller. Keep in mind this is the thumb rule