Run Times
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Pump head, expressed in feet or meters, is the definition for energy supplied to liquid by a pump. Curves, datasheets, and instruction manuals all use the term head. Users must convert pressure and flow measurements at the pump into head before comparisons may be made to performance data supplied by the pump manufacturer. This issue of Run Times covers the elements of total head (H) and ways this information may be used to evaluate the condition of the pumping system

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Energy and Head

Energy imparted to the fluid by a pump consists of useful energy in the form of pressure, fluid temperature rise and velocity, or it may become a loss through conversion to atmospheric heat and noise. All of these values may be arithmetically converted to head. Head is equal to the height of a column liquid that could be supported by the available, or useful energy. Total head is head differential between the pump inlet and outlet.

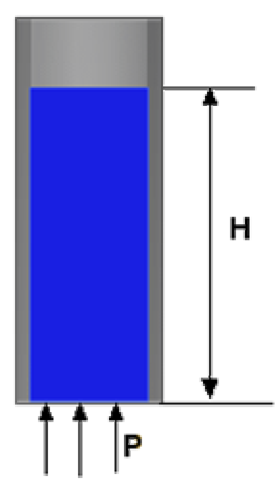
For field measurements a reasonably accurate value for total head may be obtained by calculating head values for pressure, velocity and friction; ignoring fluid temperature and noise. In the following paragraphs we will cover each of the major elements of head, and how to combine them to determine total head.

Pressure (Static) Head

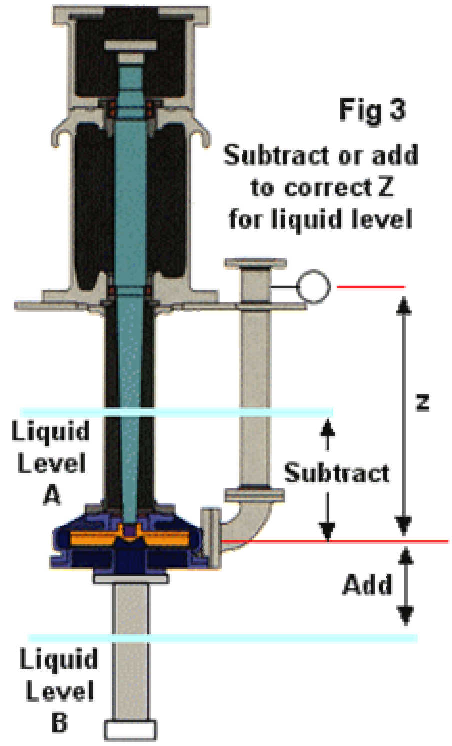
In the absence of velocity, head, or more precisely static head, is equal to the height of a static column of fluid that could be supported by a pressure (P). Fig 1.

$$h_{Meters} = \frac{P_{KPA} \times 0.102}{Sp.gr.}$$

$$h_{Feet} = \frac{P_{PSI} \times 2.31}{Sp.gr.}$$



Gages in a properly configured pump system measure static pressure at various locations. By using one of the equations above, the pressure readings may be converted to a static pressure head (h_g) for a particular gage location. The pressure head must then be corrected for any differences of elevation (z) between the gage location and the centerline of the pump impeller. In the Figures 2 & 3 the 'z' height would be added to the pressure head determined from the gage reading. The 'z' height would be subtracted if the gage were located below the impeller centerline. On vertical pumps the liquid level must be taken into account to obtain the proper gage elevation correction (fig 3).



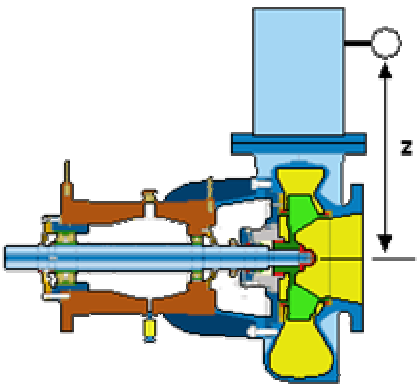


Fig 2

Velocity Head

Pumps are kinetic machines in which fluid is accelerated to some velocity. As stated earlier, head represents the total energy supplied by the pump to the fluid. At any given point in a system where flow is present, some of the available energy is in the form of velocity. To obtain a true head reading at flow rates greater than zero-flow the head associated with the fluid velocity head must be taken into account. Velocity is determined by dividing the flow rate by the cross-sectional area of the pipe.

$$V_{m^2/sec} = Q_{m^3/sec} \div A_{m^2}$$
or
$$V_{ft^2/sec} = Q_{ft^3/sec} \div A_{ft^2}$$

Velocity head(h_v) may then be calculated from the equation $\mathbf{h_v = V^2/2g}$ where 'g' = the acceleration due to gravity (9.9 meters per second per second, or 32.17 feet per second per second, at 45^o latitude.) Most pipe friction tables include a value for velocity head for each listed flow rate and pipe size.

Friction Head(h_f)

Friction head is the head associated with the friction of fluid through piping, valves and fittings. It may be obtained from pipe friction tables for any given flow rate or pipe size. Most friction tables include values for standard valves and fittings.

Total Discharge Head(h_d)

Total discharge head is the gage pressure at the discharge of the pump (h_{gd}) converted to head at the elevation of the impeller centerline, plus the velocity head at pressure gage location, plus any system friction losses (h_f) between the pump and pressure gage location.

Total Suction Head(h_s)

Total suction head is the gage pressure at the suction of the pump (h_{gs}) converted to head at the elevation of the impeller centerline, plus the velocity head at pressure gage location, plus any system friction losses (h_f) between the pump and pressure gage location.

Total Head(H) – Often called Total Dynamic Head(TDH)

Total head is the difference between total suction head and total discharge head.

$$H = (h_{gd} \pm z_d + h_v + h_f) - (h_{gs} \pm z_s + h_v + h_f)$$

Comments

- One problem that confrontusers is that flowrate is needed to calculate the velocity head and friction. This is sometimes not available. Fortunately, these are often relatively insignificant in the total head calculation. Under certain conditions, as described below, they may be negated.
- Velocity head may be ignored If the pipe diameters are the same for both the suction and discharge gage locations.
- At zero flow there is no velocity, therefore there is no velocity head and no friction head.
- Friction head is usually a relatively small number and may be ignored in pump installations where the pressure taps are within a few feet of the pump and the piping is relatively straight.
- For vertical submerged pumps without tailpipes, total head is equal to the head at the discharge pressure gage, plus the velocity head at the discharge pressure gage, plus the vertical distance to the free liquid surface of the sump or pit.
- For vertical pumps with a tailpipe and a suction lift solve for total suction head using the methodology described above. If readings are in mm or inches mercury covert the values to feet and use a negative(-) value for head.

$$1 \text{ mm hg} = 0.0133 \text{ m}(H_2O) \qquad 1 \text{ in. hg} = 1.13 \text{ ft.}(H_2O)$$

Example:

A vertical 6" x 6" pump in an open sump pumps 200 m^3/hr (880 gpm) of water with a 1.0 sp.gr. at a discharge pressure of 200 kpa (29 psi) and a suction pressure of 500 mm hg (19.7 in. hg). There are both discharge and suction gages located 2 meters (6.5 ft.) above the impeller centerline. There are no tangible friction losses between the gage connections and the pump. What is the total head being developed by the pump?

200 kpa x 0.102 = 20.4m
H_d = 20.4m

500 mm hg * 0.0133 = -6.7m
H_s = -6.7m

Because the suction and discharge are the same size the differential value of velocity head is zero. The gages are at equal elevation above the impeller centerline so they also cancel out. Frictional losses between the gage taps and the pump are negligible. Therefore the equation for total head(H) may be simplified to:

$H = h_{gd} - h_{gs}$

H = (20.4m) – (-6.7m) = 27.1m

Estimating Performance

If operating procedures and the pump manufacturer permit, the hydraulic condition of the pump may be checked by momentarily operating at, or near, zero flow.

- A total head less than that shown on the pump curve would be indicative of wear provided that speed and impeller diameter are the same for both the operating pump and the curve. If either the speed or the impeller diameter are different than the curve, the measured head may be closely approximated to the curve by applying the following equation.

$$H_{new} = H_{measured} \times (D_{installed\ impeller}/D_{curve\ impeller})^2 \times (n_{operating}/n_{curve})^2$$

- If there is no indication of wear, flow may be estimated from the manufacturer's curve by matching total head at the operating point with the corresponding head on the pump curve.

- If the measured shut-off head closely matches the manufacturer's curve but the head at the duty point falls far below the manufacturer's curve, a partial blockage upstream of the discharge tap is possible. (The suction strainer or the impeller eye are the most likely locations.)

- If wear is indicated by a measured shut-off head that is lower than the manufacturer's curve, the wear performance may be estimated by drawing a new curve parallel to the manufacturer's curve, that passes through the measured shut-off head point. The total head at the operating condition may then be used in conjunction with the new curve to estimate flow.