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Often, some of the most costly problems are the result of the most fundamental errors. Recently, while reviewing some of our past issues, I realized that we have not discussed some of the fundamentals of pump operation. Like many things, a thorough understanding of basic principles is often a key to successfully solving complicated problems. Therefore, in the next few issues, we'll present some of the basics of centrifugal pump operation. As always, we welcome your feedback and comments.

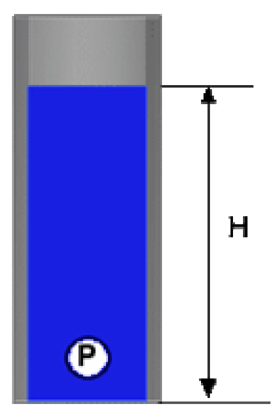
Dale B. Andrews

Dale B. Andrews – Editor

A centrifugal pump is a kinetic device. Liquid entering the pump receives kinetic energy from the rotating impeller. The centrifugal action of the impeller accelerates the liquid to a high velocity, transferring mechanical (rotational) energy to the liquid. That kinetic energy is available to the fluid to accomplish work. In most cases, the work consists of the liquid moving at some velocity through a system by overcoming resistance to flow due to friction from pipes, and physical restrictions from valves, heat exchangers and other in-line devices, as well as elevation changes between the liquid's starting location and final destination. When velocity is reduced due to resistance encountered in the system, pressure (P) increases. As resistance is encountered, the liquid expends some its energy in the form of heat, noise, and vibration in overcoming that resistance. The result is that the available energy in the liquid decreases as the distance from the pump increases. The actual energy available for work at any point in a system is a combination of the available velocity and pressure energy at that point.

<u>Head</u>

Head (H) is the term that is used to define the energy supplied to the liquid by the pump. It is independent of the type of liquid being pumped. Head is expressed in Feet or Meters. In the absence of any velocity, it is equal to the height of a static column of liquid that could be supported by the pressure (P) at a given point in the system. In practice, pressure is usually measured by a pressure sensing device such as a gage or pressure transducer.



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Head (H) is the ratio of pressure to the Density (Specific weight) of a liquid. For water at 60°F, head (H) may be calculated, from a pressure reading, using the following equation:

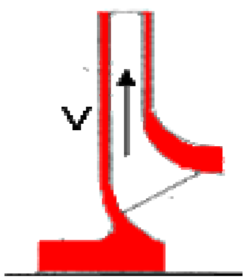
$$H = \frac{Pressure(\frac{lbs}{in^2}) \times 144 \frac{in^2}{ft^2}}{62.4 \frac{lbs}{ft^3}}$$

This may be simplified to **H = P * 2. 31**. The units cancel out so that only feet remain. For a liquid with a Density other than water, divide by the specific gravity of the liquid.[1]

$$H = \frac{P \times 2.31}{Sp.Gr.}$$

Because specific gravity is an index number (dimensionless) the units remain as feet of head.[2]

Flow Rate



Flow rate is determined by the impeller geometry and its rotational speed. Pump designers manipulate the impeller vane design to achieve an optimum throughput velocity[3] for an impeller. The throughput velocity (ft/sec) multiplied by the usable area of the impeller inlet (ft^2) yields the flow rate (ft^3/sec). Every impeller has one optimum design flow rate for a given speed and diameter. This is the best efficiency point of the pump. At other flow rates there will be a mismatch between the vane angle at the pump inlet and the flow rate, resulting in increased turbulence and loss of efficiency within the pump.

Total Dynamic Head

Total Dynamic Head (TDH) is the difference in head between the pump outlet and inlet. In actual practice, readings must be corrected for piping losses, gauge

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[1] Specific gravity is the ratio of the Density of a liquid to the Density of water @ 60^0F.

[2] In the SI system pressure Head is expressed in Meters (M) and Pressure is expressed in Kilopascals (KPA). (PSI = KPA * 0.145). H = M^3/hr * Specific gravity/366

[3] Also called the meridional velocity. It is the velocity of the liquid traveling within an impeller vane passage from inlet to outlet.

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location and differences in pipeline velocity between the measurement point son the pump inlet and outlet; all unique to the specific pump/system setup.

Pump Efficiency

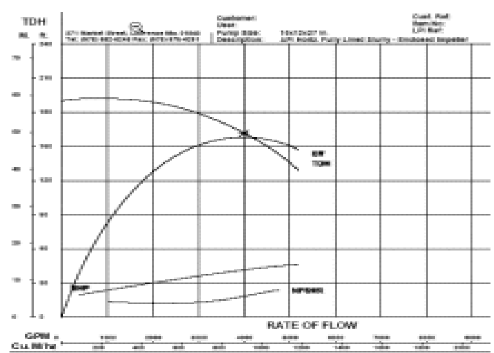
Pump efficiency is the ratio of hydraulic horsepower to the brake horsepower required to drive the pump. Hydraulic horsepower is the kinetic power available at the pump discharge. It is calculated by the following equation[4].

$$HHP = \frac{Flow(USGPM) \times TDH(ft) \times SP.GR}{3960}$$

Brake horsepower is measured at the pump input shaft by a torque-meter coupling or similar device. The difference between brake horsepower and hydraulic horsepower is the amount of power consumed by mechanical losses, noise, heat, viscous drag, and internal recirculation. Our Sept 2004 issue discusses this topic in greater detail.

Characteristic Curves

Curves are available from pump manufacturers that depict the 'as new' performance characteristics for any given pump model. These may be either generic catalog curves that represent typical values, or they may be test curves that show the actual performance of a customer's particular pump unit. Performance curves show plots of TDH, Efficiency, BHP and, when specified, NPSHR[5] as functions of flow rate[6].



The shape of a pump curve is primarily determined by the geometry of the impeller. High flow - low head pumps typically have steeper curves than low flow - high head units.

The performance of a pump when placed in a system is a function of the interaction between the pump and system as defined by their relative characteristics. Next month, we'll discuss system basics, including start-up conditions, operation, and troubleshooting.

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[4] To obtain Kilowatts multiply HP * 0.746

[5] Net Positive Suction Head Required. The minimum absolute suction pressure required by the pump. See the Oct 2004 issue for a discussion of NPSHR.

[6] Characteristic curves are based on the pump performance while pumping clean water at 20°C (68°F).