# 200.0 Definitions and Descriptions of Terms

## 201.0 *Definition*

This section contains the definition of all terms used in this testing procedure. Nomenclature and typical units are also listed in Section 801.0.

## 202.0 *Centrifugal Pumps*

A pump in which pressure is developed principally by the action of centrifugal force.

## 203.0 *Newtonian Fluids*

A liquid which resists shear in direct proportion to the rate of shear.

## 204.0 *Datum*

The reference from which all elevations are measured.

## 205.0 *Specific Gravity, (s)*

The dimensionless ratio of the specific weight of the liquid to the specific weight of water under reference conditions of temperature and pressure. It is primarily a function of temperature, but operating pressure and elevation will have some effect on specific gravity and should be evaluated.

## 206.0 *Vapor Pressure*, ($h_{vpa}$)

The absolute pressure exerted by the vapor of a liquid at a given temperature.

## 207.0 *Viscosity*, ($\mu$)

The measure of a fluid's tendency to resist an internal shearing force.

## 208.0 *Pressure Head*, ($h_p$)

The pressure energy per unit weight of liquid at a given location corrected to datum elevation.

## 209.0 *Total Discharge Head,* ($h_d$)

The reading of a pressure gauge at the discharge of the pump, converted to column of liquid and referred to datum, plus the velocity head at the point of gauge attachment.

## 210.0 *Total Suction Head,* ($h_s$)

The reading of a pressure gauge at the suction of the pump, converted to column of liquid and referred to datum, plus the velocity head at the point of gauge attachment.

210.1 *Total Suction Lift, ($h_{gs}$):* Suction lift exists where the total suction head is below atmospheric pressure. Total suction lift, as, determined during testing, is the reading of a liquid manometer at the suction nozzle of the pump, converted to column of liquid and referred to datum, minus the velocity head at the point of gauge attachment.

## 211.0 *Total Head,* (H)

The measure of the work, ft lb./ lb. of the liquid, imparted to the liquid by the pump. Therefore, pump total head is the algebraic difference between the total discharge head and total suction head.

## 212.0 *Static Discharge Head,* ($h_{sd}$)

The portion of the discharge pressure exerted on the pump, referred to datum and converted to column of liquid pumped, that is due to the net liquid elevation above the pump discharge plus the pressure that is acting on this liquid surface is defined as the Static Discharge Head. This pressure can be measured with a discharge pressure gauge and without the pump running.

## 213.0 *Static Suction Head,* ($h_{ss}$)

The hydraulic pressure exerted by the liquid against the pump suction as indicated by a pressure gauge, manometer or similar devices, referred to datum and converted to column of the liquid being pumped, without the pump running.

## 214.0 *Suction Surface Pressure*, ($h_{ps}$)

The pressure exerted on the surface of the liquid at the suction sources of the pump.

## 215.0 *Discharge Surface Pressure*, ($h_{pd}$)

The pressure exerted on the surface of the liquid in the vessel to which the pump discharges.

## 216.0 *Friction Head Loss*, ($h_f$)

The resistance to flow in a pumping system as indicated by loss of head. Suction Friction Head will be designated as $h_{fs}$. Discharge Friction Head will be designated as $h_{fd}$.

## 217.0 *Gravitational Acceleration*, (g)

The gravitational constant for customary unit is 32.2 ft/ sec$^2$ and 9.81 m/ sec$^2$ for SI units at sea level.

## 218.0 *Velocity Head*, ($h_v$)

The energy component in a pumping system that represents the kinetic or "velocity" energy in a moving liquid at the point being considered in the system. It is equivalent to the vertical distance the mass of liquid would have to fall (in a perfect vacuum) to acquire the velocity "v" and is expressed as:

$$h_v = \frac{v^2}{2g}$$

Suction Velocity Head will be designated $h_{vs}$ and Discharge Velocity Head will be designated $h_{vd}$.

## 219.0 *Pump Efficiency*, (eff)

The output (hydraulic) horsepower supplied by the pump divided by the input (shaft) horsepower expressed as a percentage.

## 220.0 Net Positive Suction Head Required, ($NPSH_R$)

The $NPSH_R$ is defined as the NPSH applied to the pump at a given flow rate that causes sufficient cavitation to reduce the Total Head by 3%. This is an established pump industry standard procedure (see reference 805.1) used to indirectly measure, at a reasonable cost, the suction side pressure loss inside a pump before mechanical action increases the liquid pressure. The measurement is taken while pumping water with a minimum of inlet stream turbulence (i.e. no close connected double elbows), no entrained gas, and frequently with water that has most dissolved gas removed.

220.1 Discussion and considerations for $NPSH_R$

220.1.1 *Net Positive Suction Head Required* ($NPSH_R$) is a crucial performance limitation of any centrifugal pump. It must be considered with equal importance to head, capacity, and discharge pressure when designing a pumping system and selecting a pump for a given service. The $NPSH_R$ of a given pump is a function of the impeller design, diameter and speed, and is established by specific and well-defined procedures by test using water as the testing fluid. A pump, in order to operate reliably and with the minimum of maintenance, must be supplied with a $NPSH_A$ (defined below) in excess of $NPSH_R$ value. Reference 805.1 describes more detailed information on this subject and the appropriate margin between $NPSH_A$ and $NPSH_R$. Performance test results will be meaningless if adequate margin does not exist.

220.1.2 *Net Positive Suction Head Available,* ($NPSH_A$): A detailed calculation of $NPSH_A$ should have been done prior to purchasing the pump. Preparations for field-testing should determine adequate $NPSH_A$ to $NPSH_R$ margin actually exists prior to conducting a test. Insufficient margin will reduce pump hydraulic performance compared to published test curves supplied by the manufacturer. Excessive turbulence, entrained gas and liquid with large quantities of dissolved gas will decrease the $NPSH_A$ values obtained during the test.

220.1.3 $NPSH_A$ equals the suction surface pressure at the liquid surface, minus the vapor pressure, plus the suction static head (all in column of liquid) minus the friction loss through the suction system. If suction pressure is measured at the pump suction flange, the friction loss ($h_{fs}$) value is zero.

$$NPSH_A = h_{psa} + h_{ss} - h_{fs} - h_{vpa}$$

$h_{psa}$ = suction surface pressure, absolute
$h_{ss}$ = static suction head (plus or minus depending on actual conditions)
$h_{fs}$ = suction friction head
$h_{vpa}$ = vapor pressure of liquid, absolute, at temperature.

220.2 Two common $NPSH_A$ situations are shown in Figures 220.2.1 and 220.2.2.

220.2.1 Pressurized tank on suction (see Figure 220.2.1)

$$\text{NPSH}_A = \text{const}\,\frac{h_{psa} - h_{vpa}}{s} + h_{ss} - h_{fs}$$

Where:
const = 2.31 for customary units to convert PSI to feet of liquid
const = 0.102 for SI units to convert kilopascals to meters of liquid

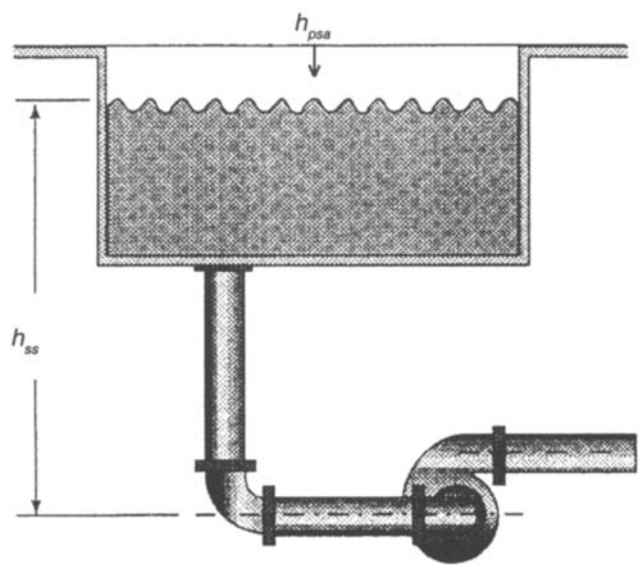


**Figure 220.2.1 Pressurized tank on suction. $\text{NPSH}_A$ is measured at pump center line and face of inlet flange.**

220.2.2 Suction lift (see Figure 220.2.2)

$$\text{NPSH}_A = \text{const}\,\frac{h_{psa} - h_{vpa}}{s} - h_{ss} - h_{fs}$$

Where const = 2.31 for customary units
const = 0.102 for SI units

Note: $h_p$ equals the atmospheric pressure on an open tank.

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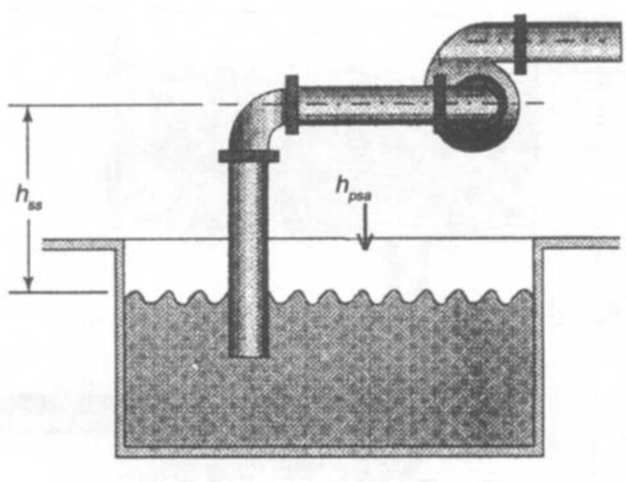


**Figure 220.2.1 Pressurized tank on suction. $NPSH_A$ is measured at pump center line and face of inlet flange.**

220.2.2 Suction lift (see Figure 220.2.2)

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Where const = 2.31 for customary units
const = 0.102 for SI units

Note: $h_p$ equals the atmospheric pressure on an open tank.

220.3.1 Manufacturers expect the user to supply an $NPSH_A$ that exceeds the published $NPSH_R$ value. The margin between the $NPSH_A$ and $NPSH_R$ becomes a commercial decision and should be properly evaluated by the person selecting the pump and developing the piping system. See paragraph 220.1.1 & reference 805.1

220.3.2 Anyone developing pumping systems designed with these minimum recommended margins should consider testing the equipment to be delivered to confirm that it meets the published data (see reference 805.1). The following information should be considered when ordering the pumps to decide if tests should be conducted:

220.3.2.1 Most manufacturers do not hydraulically test every pump unless required to do so by the purchaser. General pump curves reflect typical performance for a series of pumps. For critical applications it may be prudent for the purchaser to witness the test.

220.3.2.2 The “first” test of a specific pump may result in higher $NPSH_R$ and Total Head values than indicated by the published data due to casting variations of the casing and impeller. To correct this condition, the manufacturer may have to grind the controlling surfaces of the impeller and case to reduce the $NPSH_R$ and reduce the impeller diameter to reduce the total discharge head, $h_d$ within acceptable tolerances. After such modifications are made, the pump is retested to confirm the results of the rework. Test specifications should be included in the purchase order when it is deemed necessary to test a pump.

220.3.2.3 Published $NPSH_R$ values are not guaranteed by the supplier unless so specified by the purchaser at the time the order is placed and the pump is $NPSH_R$ tested.

220.3.2.4 The testing procedure followed by most manufacturers (see reference 805.1) typically yield the minimum information, which is not considered adequate for most critical chemical plant services, especially as it relates to $NPSH_R$ testing. Centrifugal pump test specifications may be made part of purchase specifications.

220.3.2.5 Cavitation that affects the total head developed by the pump starts at values well above the published $NPSH_R$ values.

220.3.2.6 $NPSH_A$ values only slightly less than the $NPSH_R$ values will cause a dramatic loss in pump head, which causes the flow in an actual system to surge and the systems to become hydraulically unstable. During this type of operation, pump vibration increases causing increased equipment maintenance. Actual fluid and piping conditions will normally decrease the $NPSH_A$.

220.3.2.7 The $NPSH_R$ established in these tests will never be less than that in actual operation. Also restricting clearances in the pump wear (impeller and casing wear rings), will increase the $NPSH_R$.