

Formulas for pump system and liquid flow analysis (Imperial units)

www.pumpfundamentals.com

J. Chaurette June 2016

Flow rate vs velocity for pipes

$$v \text{ (ft/s)} = \frac{0.4085 \times q \text{ (gpm)}}{(d(\text{in}))^2}$$

Pressure to head

$$h(\text{ft}) = 2.31 \times \frac{p \text{ (psi)}}{SG}$$

Reynolds number

$$Re = 7746 \times \frac{v \text{ (ft/s)} \times d \text{ (in)}}{\nu \text{ (cSt)}}$$

Friction parameter - turbulent flow (Swamee-Jain)

$$f = \frac{0.25}{\left(\log_{10} \left(\frac{\varepsilon \text{ (in)}}{3.7 \times d \text{ (in)}} + \frac{5.74}{Re^{0.9}} \right) \right)^2}$$

Friction parameter - laminar flow

$$f = \frac{64}{Re}$$

Pump power

$$P \text{ (hp)} = SG \times \frac{q \text{ (gpm)} \times \Delta HP \text{ (ft)}}{3960 \times \eta}$$

Pipe friction factor (Darcy-Weisbach)

$$\frac{\Delta h \text{ (ft)}}{L \text{ (100 ft pipe)}} = 1200 \times f \times \frac{(v \text{ (ft/s)})^2}{d \text{ (in)} \times 2 \times g \text{ (ft/s}^2\text{)}}$$

CONSTANTS AND DATA

typical discharge pump velocity - $v = 9$ to 12 ft/s

acceleration due to gravity - $g = 32.17$ (ft/s²)

viscosity - $\nu = 1$ cSt for water at 20 C

pipe roughness - $\varepsilon = 0.00015$ ft for steel

specific gravity - $SG = 1$ for water at 20 C

Reynolds number - $Re < 2000$ for laminar flow, $Re > 4000$ for turbulent flow

atmospheric pressure - $p = 14.7$ psia at sea level

pump efficiency - η from pump performance curve

Pump total head

$$\Delta HP \text{ (ft)} = \Delta HF_{1-2} \text{ (ft)} + \Delta HE_{EQ1-2} \text{ (ft)} + \frac{(v_2 \text{ (ft/s)})^2 - (v_1 \text{ (ft/s)})^2}{2 \times g \text{ (ft/s}^2\text{)}} + (z_2 \text{ (ft)} + H_2 \text{ (ft)}) - (z_1 \text{ (ft)} + H_1 \text{ (ft)})$$

Locations 1 and 2 identify the position of the liquid particles from the inlet to the outlet of the system

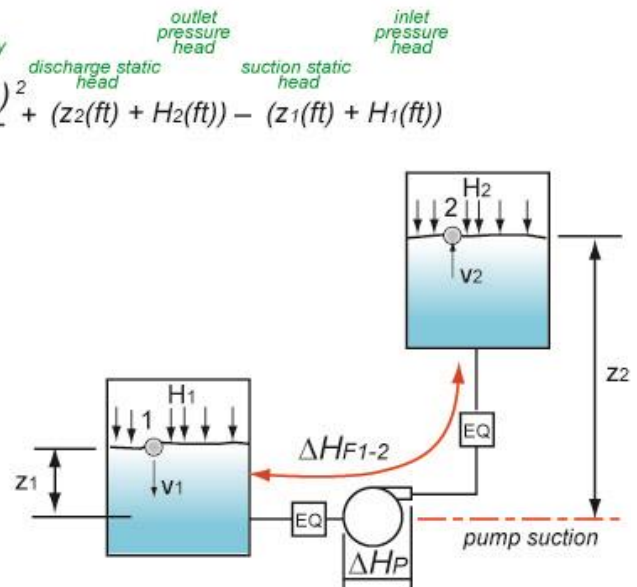
EQ equipment such as: fittings, manual valves, auto. valves, filters, etc.

H_1 and H_2 are the pressure heads on the liquid in their respective tanks, if the pressure head is atmospheric H_1 and $H_2 = 0$

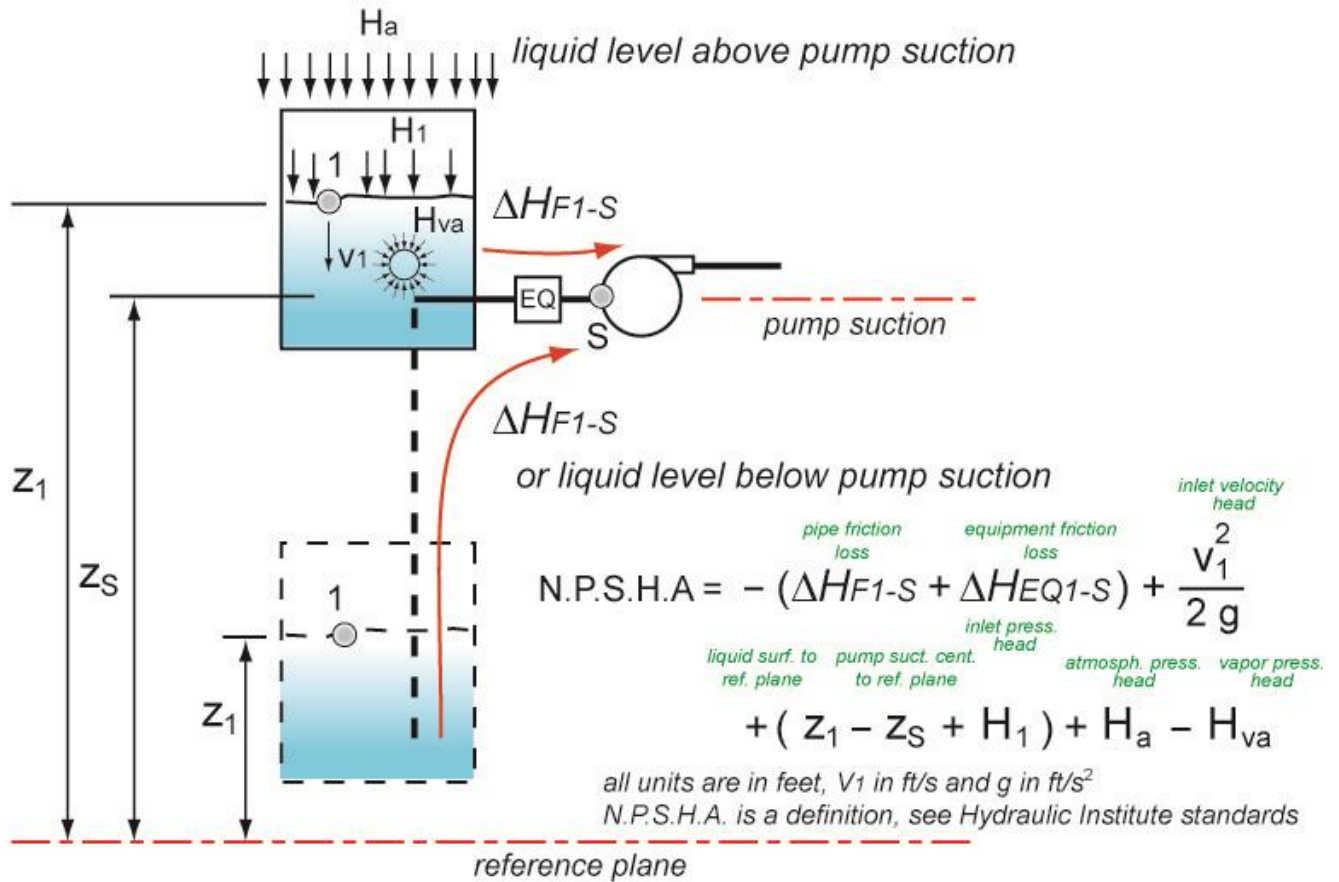
v_1 and v_2 are the liquid surface velocities in each tank, the velocity heads are small

If there is no equipment and fitting loss is negligible, tanks are atmospheric and we neglect the velocity heads, we have:

$$\Delta HP \text{ (ft)} = \Delta HF_{1-2} \text{ (ft)} + z_2 \text{ (ft)} - z_1 \text{ (ft)}$$



Net positive suction head available (N.P.S.H.A.)



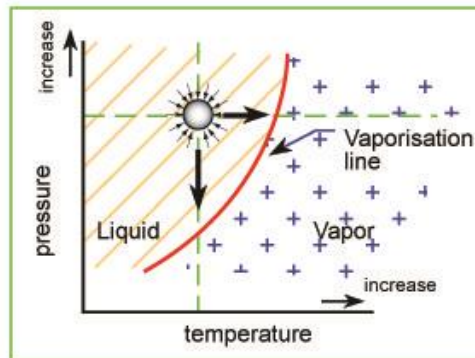
CONSTANTS AND DATA

typical suction pump velocity - $v = 3$ to 6 ft/s

atmospheric pressure - $H_a = 14.7$ psia at sea level, depends on elevation

vapor pressure - H_{va} depends on nature of liquid and temperature

vapor pressure varies with temperature and pressure, as pressure decreases at constant temperature vaporisation occurs, this is why vapor pressure is subtracted from all other pressure terms, to ensure that at a minimum the N.P.S.H.A. is above the vapor pressure



Formulas for pump system and liquid flow analysis (metric units)

www.pumpfundamentals.com

J. Chaurette June 2016

Flow rate vs velocity for pipes

$$v \text{ (ft/s)} = \frac{21.22 \times q \text{ (l/m)}}{(d(\text{mm}))^2}$$

Reynolds number

$$Re = 1000 \times \frac{v \text{ (m/s)} \times d \text{ (mm)}}{\nu \text{ (cSt)}}$$

Friction parameter - laminar flow

$$f = \frac{64}{Re}$$

Pump power

$$P \text{ (kW)} = SG \times \frac{q \text{ (l/min)} \times \Delta HP \text{ (m)}}{6128 \times \eta}$$

Pressure to head

$$h(\text{ft}) = 0.102 \times \frac{p \text{ (kPa)}}{SG}$$

Friction parameter - turbulent flow (Swamee-Jain)

$$f = \frac{0.25}{\left(\log_{10} \left(\frac{\varepsilon \text{ (in)}}{3.7 \times d \text{ (in)}} + \frac{5.74}{Re^{0.9}} \right) \right)^2}$$

Pipe friction factor (Darcy-Weisbach)

$$\frac{\Delta h \text{ (m)}}{L \text{ (100 m pipe)}} = 10^5 \times f \times \frac{(v \text{ (m/s)})^2}{d \text{ (m)} \times 2 \times g \text{ (m/s}^2\text{)}}$$

CONSTANTS AND DATA

typical discharge pump velocity - $v = 2.5$ to 5 m/s

acceleration due to gravity - $g = 9.81$ (m/s²)

viscosity - $\nu = 1$ cSt for water at 20 C

pipe roughness - $\varepsilon = 0.0457$ mm for steel

specific gravity - $SG = 1$ for water at 20 C

Reynolds number - $Re < 2000$ for laminar flow, $Re > 4000$ for turbulent flow

atmospheric pressure - $p = 101$ psia at sea level

pump efficiency - η from pump performance curve

Pump total head

$$\Delta HP \text{ (m)} = \Delta HF_{1-2} \text{ (m)} + \Delta HEQ_{1-2} \text{ (m)} + \frac{(v_2 \text{ (m/s)})^2 - (v_1 \text{ (m/s)})^2}{2 \times g \text{ (m/s}^2\text{)}} + (z_2 \text{ (m)} + H_2 \text{ (m)}) - (z_1 \text{ (m)} + H_1 \text{ (m)})$$

Locations 1 and 2 identify the position of the liquid particles from the inlet to the outlet of the system

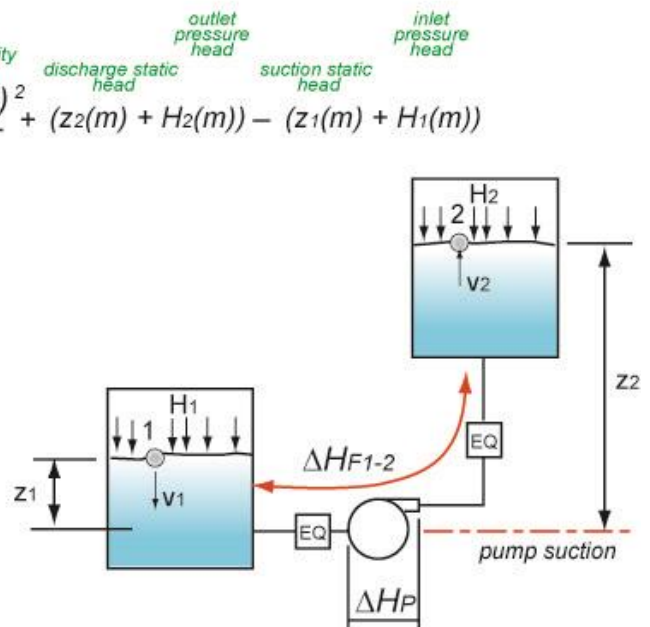
EQ equipment such as: fittings, manual valves, auto. valves, filters, etc.

H_1 and H_2 are the pressure heads on the liquid in their respective tanks, if the pressure head is atmospheric H_1 and $H_2 = 0$

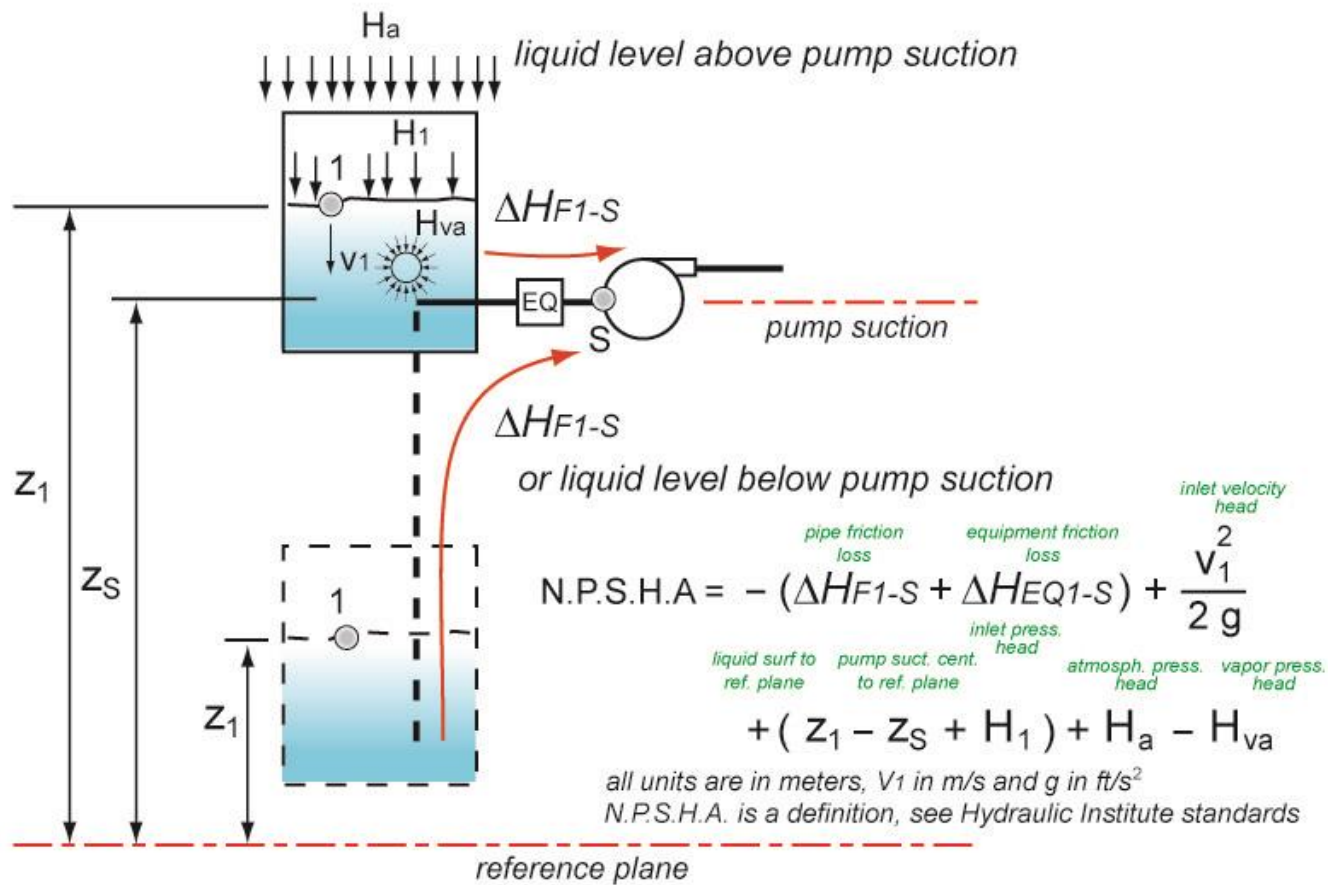
v_1 and v_2 are the liquid surface velocities in each tank, the velocity heads are small

if there is no equipment and fitting loss is negligible, tanks are atmospheric and we neglect the velocity heads, we have:

$$\Delta HP \text{ (m)} = \Delta HF_{1-2} \text{ (m)} + z_2 \text{ (m)} - z_1 \text{ (m)}$$



Net positive suction head available (N.P.S.H.A.)



CONSTANTS AND DATA

typical suction pump velocity - $v = 1$ to 3.6 m/s

atmospheric pressure - $H_a = 101$ kPa at sea level, depends on elevation

vapor pressure - H_{va} depends on nature of liquid and temperature

vapor pressure varies with temperature and pressure, as pressure decreases at constant temperature vaporisation occurs, this is why vapor pressure is subtracted from all other pressure terms, to ensure that at a minimum the N.P.S.H.A. is above the vapor pressure

