For a particular pump where the impeller of diameter D_1, is replaced by an impeller with a slightly different diameter D_2 the following equations hold

$$\frac{Q_1}{Q_2}=\left(\frac{N_1}{N_2}\right)\left(\frac{D_1}{D_2}\right) \quad \text{---------------------------------}(13)$$

$$\frac{\Delta h_1}{\Delta h_2}=\left(\frac{N_1}{N_2}\right)^2\left(\frac{D_1}{D_2}\right)^2 \quad \text{---------------------------------}(14)$$

$$\frac{P_{E1}}{P_{E2}}=\left(\frac{N_1}{N_2}\right)^3\left(\frac{D_1}{D_2}\right)^3 \quad \text{---------------------------------}(15)$$

The characteristic performance curves are available for a centrifugal pump operating at a given rotation speed, equations (13), (14), and (15) enable the characteristic performance curves to be plotted for other operating speeds and for other slightly impeller diameters.

Example -5.5-

A volute centrifugal pump with an impeller diameter of 0.02 m has the following performance data when pumping water at the best efficiency point (bep). Impeller speed N = 58.3 rev/s capacity Q = 0.012 m^3/s, total head Δh = 70 m, required NPSH = 18 m, and power = 12,000 W. Evaluate the performance data of an homologous pump with twice the impeller diameter operating at half the impeller speed.

Solution:

Let subscripts 1 and 2 refer to the first and second pump respectively,

$N_1/N_2 = 2$, $D_1/D_2 = 1/2$

Ratio of capacities

$$\frac{Q_1}{Q_2}=\left(\frac{N_1}{N_2}\right)\left(\frac{D_1}{D_2}\right)^3 = 2\ (1/8) = 1/4$$

$\Rightarrow$ Capacity of the second pump $Q_2 = 4\ Q_1 = 4(0.012) = 0.048\ m^3/s$

Ratio of total heads

$$\frac{\Delta h_1}{\Delta h_2}=\left(\frac{N_1}{N_2}\right)^2\left(\frac{D_1}{D_2}\right)^2 = 4\ (1/4) = 1$$

$\Rightarrow$ Total head of the second pump $\Delta h_2 = \Delta h_1 = 70$ m

Ratio of powers

$$\frac{P_{E1}}{P_{E2}}=\left(\frac{N_1}{N_2}\right)^3\left(\frac{D_1}{D_2}\right)^5 = 8\ (1/32) = ¼$$

assume $\frac{P_{B1}}{P_{B2}}=\frac{P_{E1}}{P_{E2}}=\frac{1}{4}$

$\Rightarrow$ Break power of the second pump $P_{B2} = 4\ P_{B1} = 4(12{,}000) = 48{,}000$ W

$$\frac{NPSH_1}{NPSH_2}=\left(\frac{N_1}{N_2}\right)^2\left(\frac{D_1}{D_2}\right)^2 = 4\ (1/4) = 1$$

$\Rightarrow$ NPSH of the second pump $NPSH_2 = NPSH_1 = 18$ m

5.10 Centrifugal Pumps in Series and in Parallel

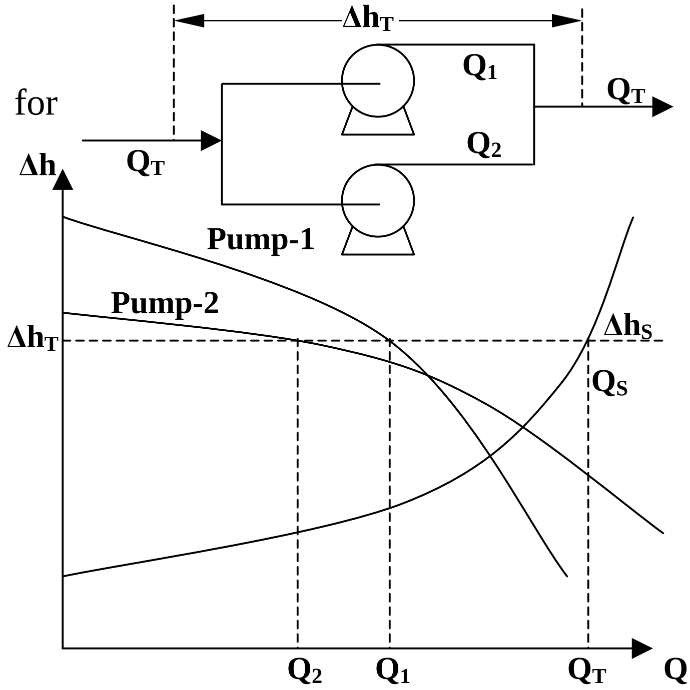
5.10.1 Centrifugal Pumps in Parallel

Consider two centrifugal pumps in ***parallel***. The total head for the pump combination (Δh_T) is the same as the total head for each pump,

$\Delta h_T = \Delta h_1 = \Delta h_2$

$Q_T = Q_1 + Q_2$

The operating characteristics curves for two pumps in parallel are: -



Solution by trail and error

1- Draw Δh versus Q for the two pumps and the system.
2- Draw horizontal Δh_T line and determine Q_1, Q_2, and Q_S.
3- Q_T (Total) = $Q_1 + Q_2 = Q_S$ (system).
4- If $Q_T \neq Q_S$ repeat steps 2, 3, and 4 until $Q_T = Q_S$.

Another procedure for solution

1- The same as above.
2- Draw several horizontal lines (4 to 6) for Δh_T and determine their Q_T.
3- Draw Δh_T versus Q_T.
4- The duty point is the intersection of Δh_T curve with Δh_S curve.

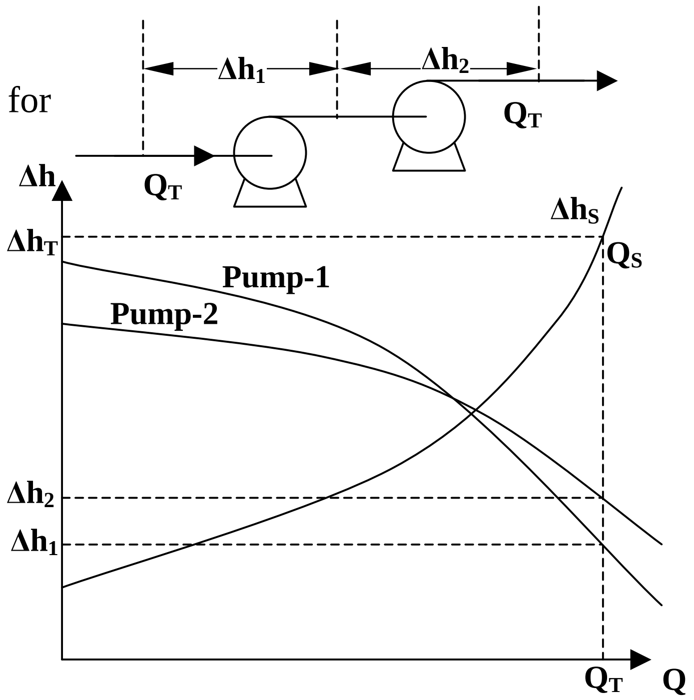
5.10.2 Centrifugal Pumps in Series

Consider two centrifugal pumps in ***series***. The total head for the pump combination (Δh_T) is the sum of the total heads for the two pumps,

$\Delta h_T = \Delta h_1 + \Delta h_2$

$Q_T = Q_1 = Q_2$

The operating characteristics curves for two pumps in series are: -



Solution by trail and error

1- Draw Δh versus Q for the two pumps and the system.
2- Draw vertical Q_T line and determine Δh_1, Δh_2, and Δh_S.
3- Q_T (Total) = $Q_1 + Q_2 = Q_S$ (system).
4- If $\Delta h_T \neq \Delta h_S$ repeat steps 2, 3, and 4 until $\Delta h_T = \Delta h_S$.

Another procedure for solution

1- The same as above.
2- Draw several Vertical lines (4 to 6) for Q_T and determine their Δh_T.
3- Draw Δh_T versus Q_T.
4- The duty point is the intersection of Δh_T curve with Δh_S curve.