12.7. Specific Speed

The first step in pump selection is to decide what class of pump (radial, mixed, or axial) will be most efficient for the given application. We usually know the flow rate Q, head rise H, and shaft rotational speed ω for the application, but not the pump size. We can form a useful dimensionless group from these quantities (including gravitational acceleration g since that's also known),

$$N_s := \text{specific speed} = \frac{\Phi^{1/2}}{\Psi^{3/4}} = \frac{\omega Q^{1/2}}{(gH)^{3/4}}. \tag{12.42}$$

This dimensionless parameter is known as the specific speed. It's customary to characterize a fluid machine by its specific speed at the design point, i.e., N_s is only given for the Best Efficiency Operating (BEP) conditions. Thus, by calculating the specific speeds for a variety of different pump types, we can create a plot that allows us to select what class of pump would be most efficient early in the design stage when we only know the desired flow rate, head rise, and shaft speed.

Notes:

(1) low Q, high $H \implies$ low $N_s \implies$ centrifugal pumps,
(2) high Q, low $H \implies$ high $N_s \implies$ axial pumps.
(3) In practice (especially in the U.S.), a combination of units are used to describe ω, Q, and H such that N_s is dimensional (signified by N_{sd}),

$$N_{sd} := \frac{\omega(\text{rpm})\sqrt{Q(\text{gpm})}}{[H(\text{ft})]^{3/4}} \tag{12.43}$$

The specific speed (N_s) and dimensional specific speed (N_{sd}) have the same physical meaning, but are different in magnitude by a constant factor,

$$N_{sd} = (2733\,\text{rpm} \cdot \text{gpm}^{1/2}/\text{ft}^{3/4})N_s. \tag{12.44}$$

(4) Given ω, Q, and H, we can calculate N_s (or N_{sd}) and, using the chart shown in Figure 12.30, determine which type of pump would be most efficient for the given conditions.

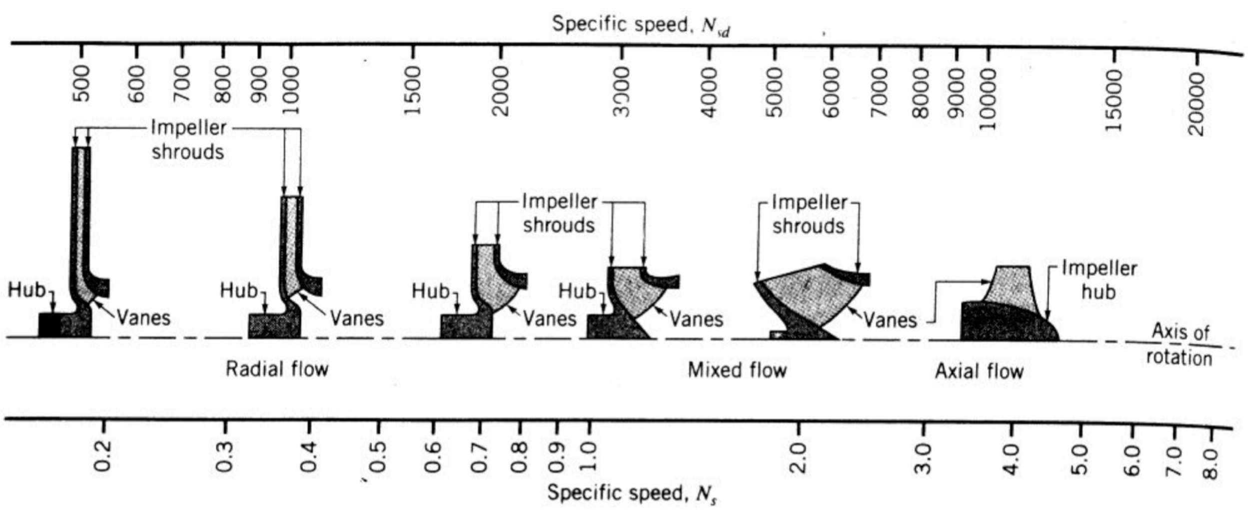


Figure 12.30. A plot of pump type as a function of specific speed. This plot is from Munson, B.R., Young, D.F, and Okiishi, T.H., *Fundamentals of Fluid Mechanics*, 3rd ed., Wiley.

Following are some rules of thumb:

(a) Positive displacement pumps are used for small flow rates (Q) and large head rises (H).

(b) Centrifugal pumps are for moderate H and large Q. Axial flow pumps are for larger Q and small H.
(c) For very large head rises, pumps are often combined in series (aka multi-stage pumps).

A small centrifugal pump, when tested at 2875 rpm with water, delivered a flowrate of 252 gpm and a head of 138 ft at its best efficiency point (efficiency is 76%). Determine the specific speed of the pump at this test condition. Sketch the impeller shape you expect. Compute the required power input to the pump.

SOLUTION:

The dimensional specific speed is given by:

$$N_{sd} = \frac{\omega\ (\text{rpm})\sqrt{Q\ (\text{gpm})}}{\left[H\ (\text{ft})\right]^{3/4}}$$

Using the given data:

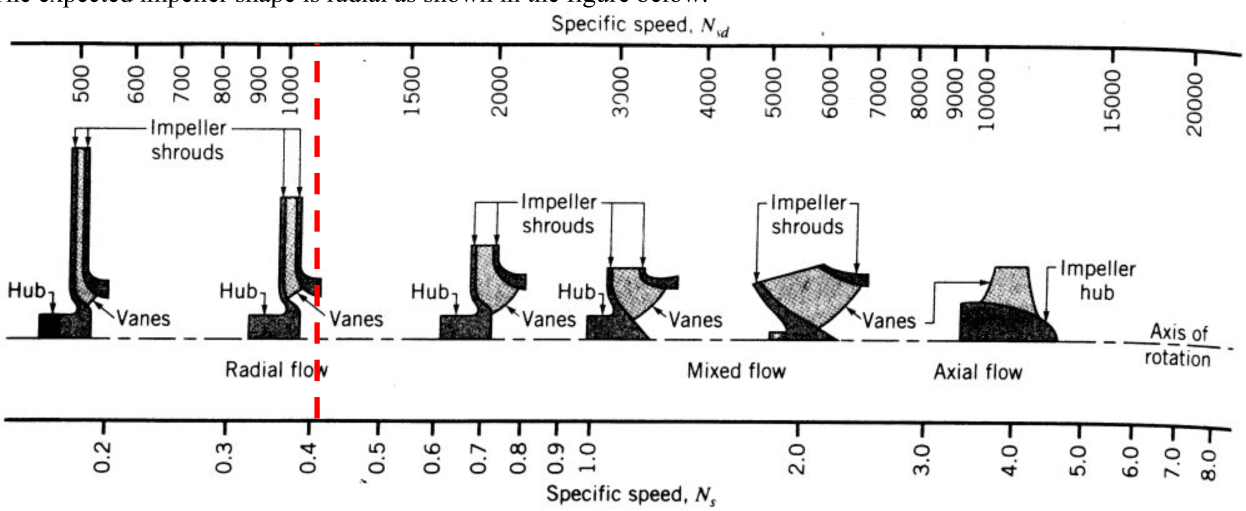
$$\boxed{N_{sd} = 1130\ \text{rpm}\cdot\text{gpm}^{1/2}/\text{ft}^{3/4}}$$

The dimensionless specific speed is:

$$N_s = \frac{N_{sd}}{2733\ \dfrac{\text{rpm}\cdot\text{gpm}^{1/2}}{\text{ft}^{3/4}}}$$

$$\boxed{N_s = 0.414}$$

The expected impeller shape is radial as shown in the figure below.



(Figure from Munson, B.R., Young, D.F., and Okiishi, T.H., *Fundamentals of Fluid Mechanics*, 3rd ed., Wiley.)

The power input to the pump is given by:

$$\dot{W}_{\text{shaft}} = \dot{W}_{\text{fluid}}/\eta_P$$

where

$$\dot{W}_{\text{fluid}} = \dot{m}gH = \rho QgH$$ (Note: 1 ft^3 = 7.48 gal, 1 hp = 550 $\text{lb}_f\cdot\text{ft/s}$, and 1 lb_f = 1 $\text{slug}\cdot\text{ft/s}^2$.)

$$\dot{W}_{\text{fluid}} = 8.80\ \text{hp}$$

$$\boxed{\dot{W}_{\text{shaft}} = 11.6\ \text{hp}}$$