Using the expression of *e* from Eq. (29.3), we have

$$R = 1 - \frac{\cot \alpha_1}{2(\cot \alpha_1 + \cot \beta_1)} \qquad (29.4)$$

The inlet blade angle β_1 of a Francis runner varies $45 - 120^o$ and the guide vane angle angle α_1 from $10 - 40^o$. The ratio of blade width to the diameter of runner B/D, at blade inlet, depends upon the required specific speed and varies from 1/20 to 2/3.

Expression for specific speed. The dimensional specific speed of a turbine, can be written as

$$N_{s_T} = \frac{NP^{1/2}}{H^{5/4}}$$

Power generated *P* for a turbine can be expressed in terms of available head *H* and hydraulic efficiency η_h as

$$P = \rho Q g H \eta_h$$

Hence, it becomes

$$N_{s_T} = N(\rho Q g \eta_h)^{1/2} H^{-3/4} \qquad (29.5)$$

Again, $N = U_1 / \pi D_1$,

Substituting U_1 from Eq. (29.2b)

$$N = \frac{V_{f_1}(\cot \alpha_1 + \cot \beta_1)}{\pi D_1} \qquad (29.6)$$

Available head *H* equals the head delivered by the turbine plus the head lost at the exit. Thus,

$$gH = e + (V_{f_2}^2 / 2)$$

since $$V_{f_1} = V_{f_2}$$

$$gH = e + (V_{f_1}^2 / 2)$$

with the help of Eq. (29.3), it becomes

$$gH = V_{f_1}^2 \cot \alpha_1 \ (\cot \alpha_1 + \cot \beta_1) + \frac{V_{f_1}^2}{2}$$

or, $$H = \frac{V_{f_1}^2}{2g}[1 + 2 \cot \alpha_1 (\cot \alpha_1 + \cot \beta_1)] \qquad (29.7)$$

Substituting the values of H and N from Eqs (29.7) and (29.6) respectively into the expression N_{s_T} given by Eq. (29.5), we get,

$$N_{s_T} = 2^{3/4} g^{5/4} (\rho \eta_h Q)^{1/2} \frac{V_{f_1}^{-1/2}}{\pi D_1} (\cot \alpha_1 + \cot \beta_1)[1 + 2 \cot \alpha_1 (\cot \alpha_1 + \cot \beta_1)^{-3/4}$$

Flow velocity at inlet V_{f_1} can be substituted from the equation of continuity as

$$V_{f_1} = \frac{Q}{\pi D_1 B}$$

where B is the width of the runner at its inlet

Finally, the expression for N_{s_T} becomes,

$$N_{s_T} = 2^{3/4} g^{5/4} (\rho \eta_h)^{1/2} (\frac{B}{\pi D_1})^{1/2} (\cot \alpha_1 + \cot \beta_1)$$

$$[1 + 2 \cot \alpha_1 \ (\cot \alpha_1 + \cot \beta_1))^{-3/4} \qquad (29.8)$$

For a Francis turbine, the variations of geometrical parameters like α_1, β_1 B/D have been described earlier. These variations cover a range of specific speed between 50 and 400. Figure 29.2 shows an overview of a Francis Turbine. The figure is specifically shown in order to convey the size and relative dimensions of a typical Francis Turbine to the readers.

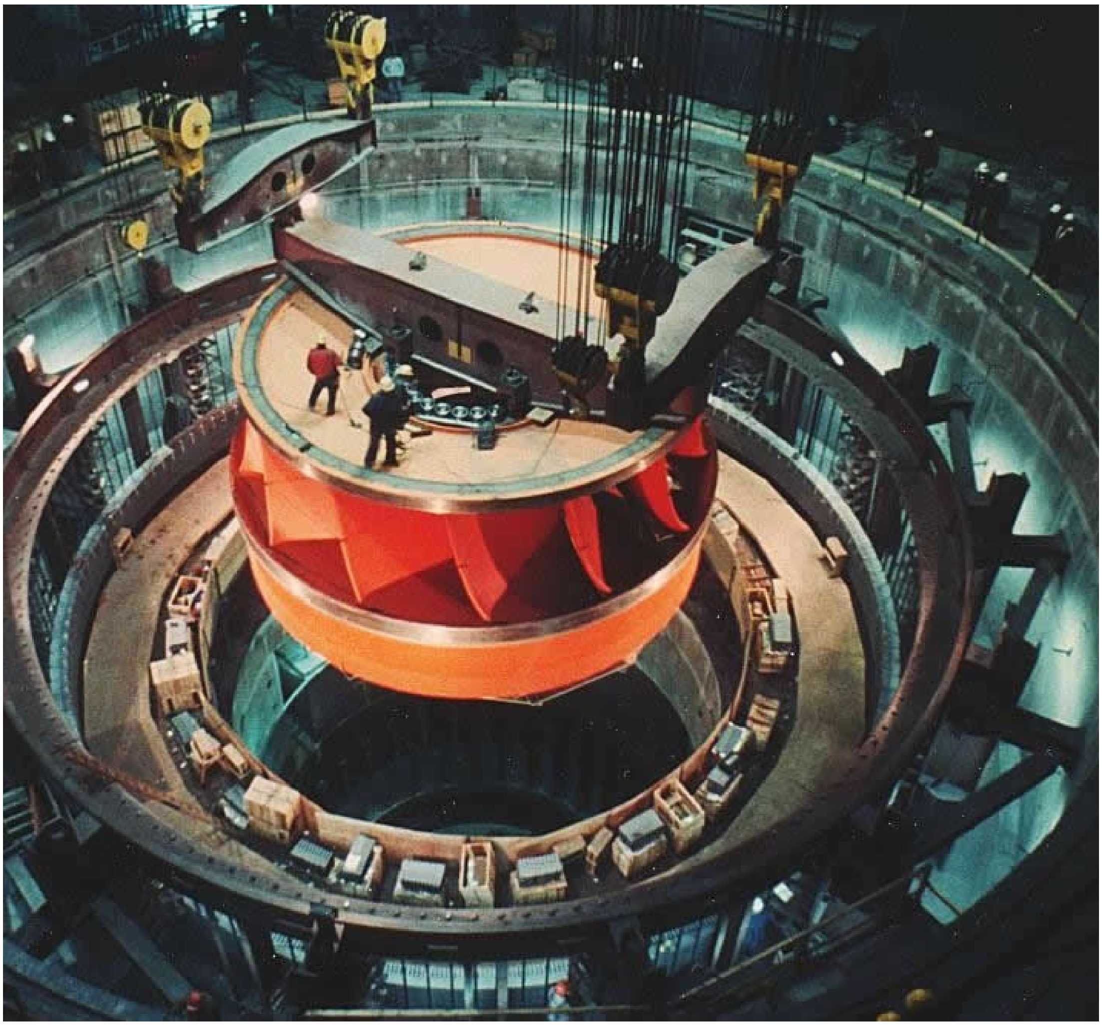

Figure 29.2 Installation of a Francis Turbine