HYDRAULIC TURBOMACHINES
Exercises 5
Cavitation

Settling level of a Francis turbine

In Figure 1, the installation of the turbine and setting level are shown.
Consider the following input data:

$C_{\bar{I}} = 0.86 \ \text{m}\cdot\text{s}^{-1}$

$Z_{\bar{B}} = 175.6 \ \text{m}$

$p_{atm} = 1.0 \ \text{bar}$

$p_v = 2343 \ \text{Pa}$

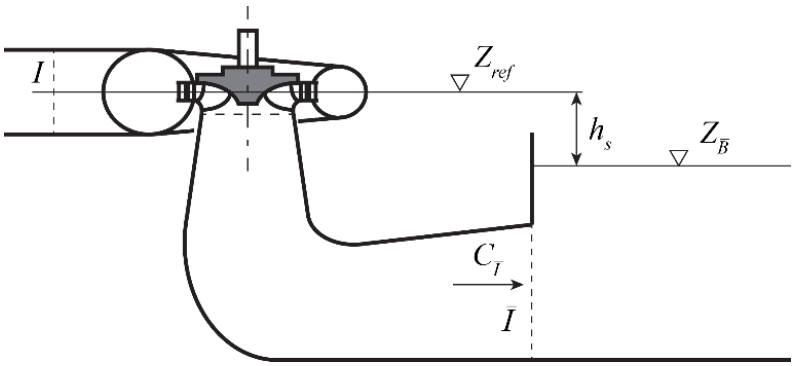

Figure 1. Machine setting level

1) Express the Net Positive Suction Specific Energy (*NPSE*) by $gH_{\bar{I}}$, Z_{ref}, and a saturated pressure p_v.

$$NPSE = gH_{\bar{I}} - \frac{p_v}{\rho} - gZ_{ref}$$

2) Express Thoma number σ defined by $\frac{NPSE}{E}$, using the setting level $h_s = Z_{ref} - Z_{\bar{B}}$, the flow velocity $C_{\bar{I}}$, the saturated pressure p_v and the atmosphere pressure p_a. Assume that the draft tube outlet is considered as a water outflow ($K_v = 1$).

$$\sigma = \frac{NPSE}{E} = \frac{\frac{p_{atm}}{\rho} + gZ_{\bar{B}} + \frac{C_{\bar{I}}^2}{2} - \frac{p_v}{\rho} - gZ_{ref}}{E} = \frac{\frac{p_{atm} - p_v}{\rho} - gh_s + \frac{C_{\bar{I}}^2}{2}}{E}$$

3) Compute Z_{ref} the setting elevation of the turbine units, to achieve a net positive suction head (NPSH) of 13.4 m.

The following condition needs to be verified:

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$$NPSH = H_{\bar{I}} - \frac{p_v}{g\rho} - Z_{ref} = 13.4\text{m}$$

The specific energy at outlet section of the machine is:

$$gH_{\bar{I}} = gZ_{\bar{I}} + \frac{p_{\bar{I}}}{\rho} + \frac{C_{\bar{I}}^2}{2} = gZ_{\bar{B}} + \frac{p_{atm}}{\rho} + \frac{C_{\bar{I}}^2}{2}$$

with $\frac{p_{\bar{I}}}{g\rho} = \frac{p_{atm}}{g\rho} + Z_{\bar{B}} - Z_{\bar{I}}$ (column of water in $\bar{\text{I}}$)

Note that the kinetic energy corresponds to the specific energy losses due to the water outflow (K_v = 1) at the draft tube outlet.

$$Z_{ref} = Z_{\bar{B}} + \frac{p_{atm} - p_v}{g\rho} + \frac{C_{\bar{I}}^2}{2g} - NPSH = 172.2$$