Reaction Turbines

It is difficult to find detailed performance data for large hydraulic turbines, perhaps because such information is often proprietory but also because test facilities for those machines are few in number. We resort here to very old test results presented by Daugherty (1920) for a $R_{T1} = 16in$ Wellman-Seaver-Morgan reaction turbine. In passing we note that the Wellman-Seaver-Morgan Company was a industry leader during the massive development of hydro-electric power in the United States in the 1910-1940 period.

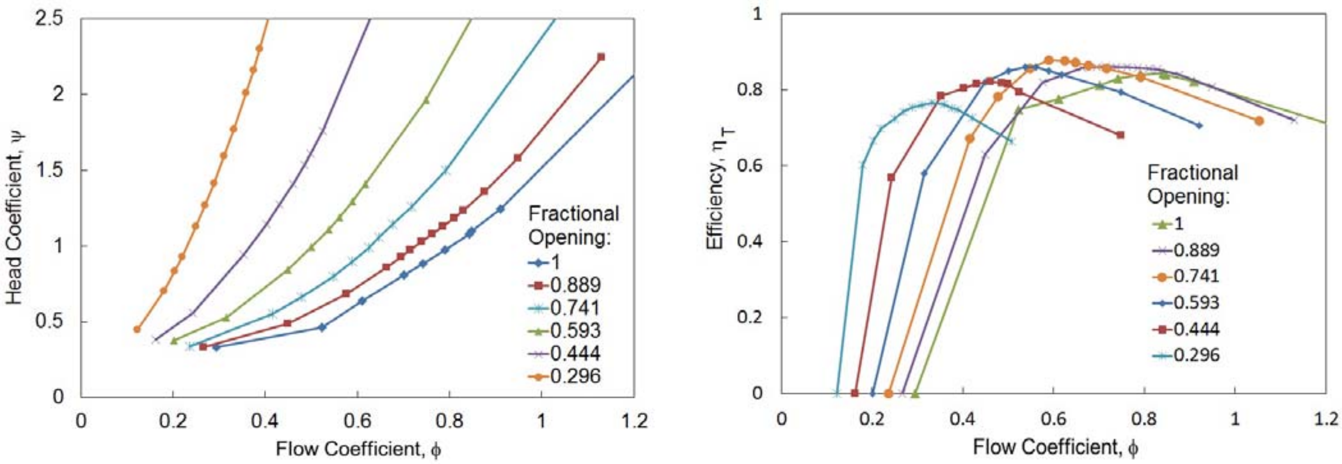

Figure 1: Head Coefficient, ψ, and efficiency, η_T, for a $R_{T1} = 16in$ Wellman-Seaver-Morgan reaction turbine at a series of gate openings (data from Daugherty (1920)).

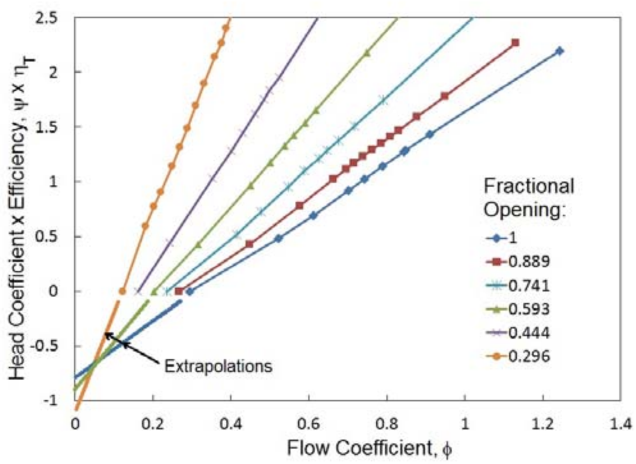

Figure 2: Head Coefficient, ψ, multiplied by the efficiency, η_T, for the data of Figure 1.

The head coefficient, ψ, and efficiency, η_T, for that hydro-turbine are presented in Figure 1 as a function of the flow coefficient, ϕ, for a series of wicket gate settings given as a fractional of the full opening. The corresponding graph of the lossless performance, $\eta_T\psi$, is given in Figure 2. This figure is the most instructive when compared with the theoretical prediction of equation (Mdi6) (or Mdi8) in the preceding section. Note that, as predicted, the relation between $\eta_T \psi$ and ϕ is linear to a very close approximation. Moreover the extrapolations demonstrate that the intercept with the vertical axis is almost the same for all gate openings and is consistent with the expected value of R_{T2}/R_{T1} of close to unity (see equation (Mdi9)). The slope of the individual lines represented by Γ_1 (equation (Mdi9)) varies substantially with the gate opening which, in turn, effects the inlet flow angle β_i. As the gate opening is decreased, the inlet swirl increases so that the flow angle, β_i, decreases, so that Γ_1 increases and, as manifest in Figure 2, the slope increases while the other geometric factors in Γ_1 remain relatively constant.

It is also useful to observe how the efficiency changes withe the flow, ϕ, and with the gate opening. The maximum efficiency of 87.7% for this old turbine occurs at a fractional gate opening of about 0.74 which allows some margin for off-design flows. That maximum of 87.7% is significantly exceeded by modern, large hydro-turbines whose efficiencies can exceed 92%. However it is also clear from Figure 1 not only that the efficiency decreases at flows both above and below design but also that the gate opening should be adjusted at those off-design flows in order to maximize the efficiency.