Thermodynamics
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Lecture 56
Tutorial Problems - Part 1

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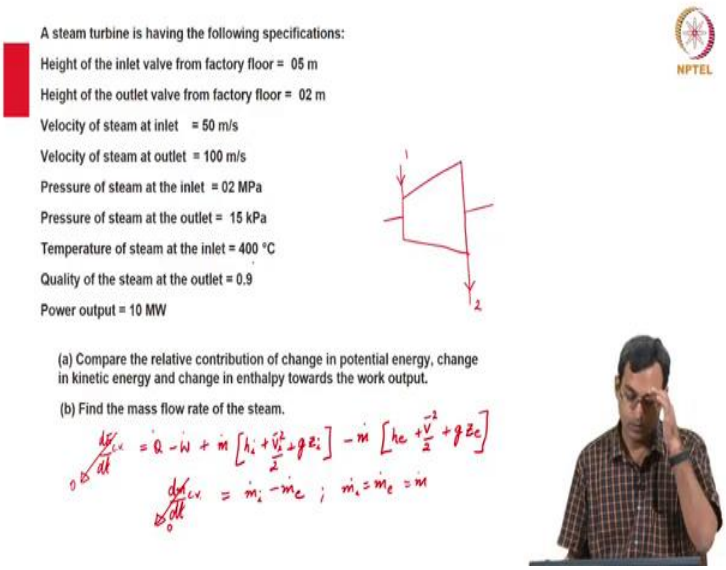
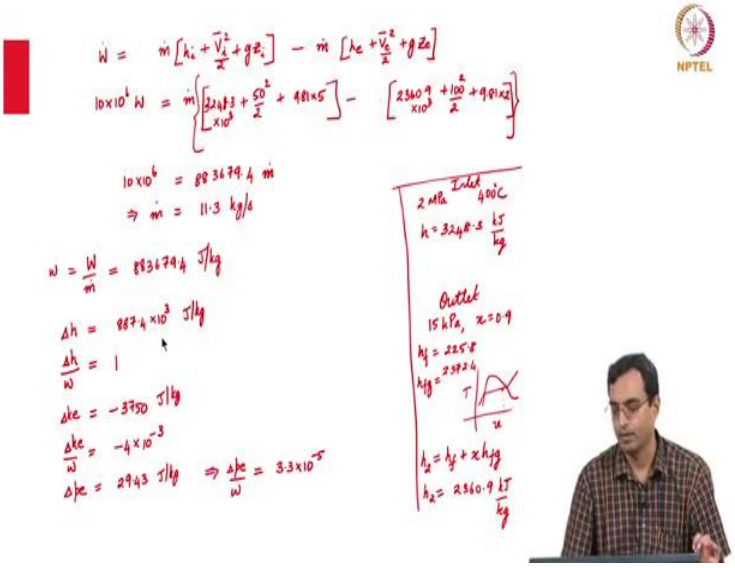
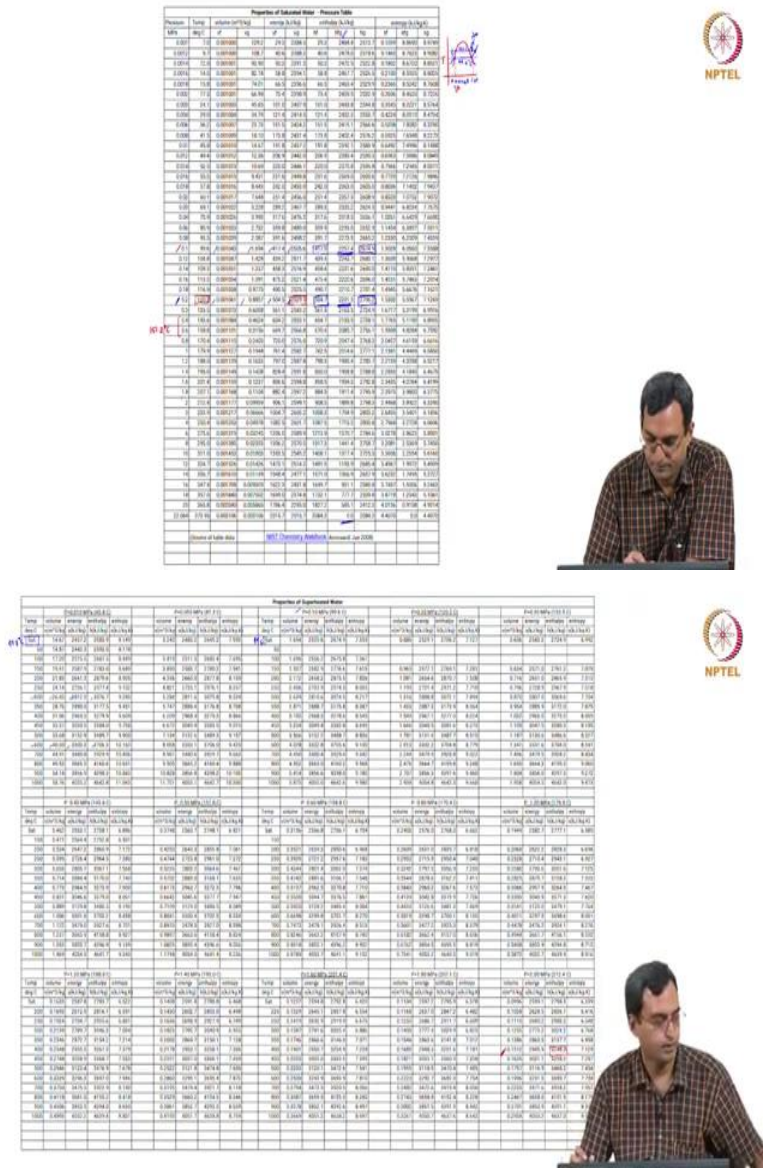


Figure 1.





Solution of the problem in Fig. 1:

A schematic of the turbine is drawn in Fig. 1. The turbine is a control volume here.

The first law for a control volume,

$$\frac{dE}{dt} = \dot{Q}_{cv} - \dot{W}_{cv} + \sum \dot{m}_i \left(h_i + \frac{1}{2}\bar{V}_i^{\,2} + gZ_i \right) - \sum \dot{m}_e \left(h_e + \frac{1}{2}\bar{V}_e^{\,2} + gZ_e \right) \ldots (1)$$

Assuming steady state and adiabatic operation,

$$\dot{W}_{cv} = \sum \dot{m}_i \left(h_i + \frac{1}{2}\bar{V}_i^{\,2} + gZ_i \right) - \sum \dot{m}_e \left(h_e + \frac{1}{2}\bar{V}_e^{\,2} + gZ_e \right),$$

$\dot{m}_i = \dot{m}_e = \dot{m}$.

Hence, mass flow rate of the steam = $\dot{m} = \frac{\dot{W}_{cv}}{\left(h_i+\frac{1}{2}\bar{V}_i^{\,2}+gZ_i\right)-\left(h_e+\frac{1}{2}\bar{V}_e^{\,2}+gZ_e\right)}$….(2)

At the inlet, at 0.2 MPa, $T_{sat} = 212$ ℃. Since, 400 ℃ > T_{sat}, the steam is in superheated zone. From the tables for superheated steam, $h_i = 3248.3\frac{kJ}{kg}$.

At the outlet, $h_e = \left[h_f + x\left(h_{fg}\right)\right]_{15\ kPa} = 2360.9\frac{kJ}{kg}$

(2) implies $\dot{m} = \frac{10\times10^6}{\left(3248.3\times10^3+\frac{50^2}{2}+9.81\times5\right)-\left(2360.9\times10^3+\frac{100^2}{2}+9.81\times2\right)} = 11.316\frac{kg}{s}$

Now, $w = \frac{\dot{W}}{\dot{m}} = 883679.4\frac{J}{kg}$

$|\Delta h| = h_i - h_e = 887.4\times10^3\frac{J}{kg}$

$\frac{|\Delta h|}{w} = 1$

$|\Delta ke| = \left|\frac{\bar{V}_i^2}{2} - \frac{\bar{V}_e^2}{2}\right| = 3750$. Hence, $\frac{|\Delta ke|}{w} = 0.004$

Similarly, $\frac{|\Delta pe|}{w} = 3.3\times10^{-5}$

Hence, the major contribution to power is from enthalpy difference. The changes in kinetic and potential energy are negligibly small.