Q2) (12 points) A 1100 MW two-pass surface condenser, whose 50 ft long 18-BWG tubes, uses seawater with tube **inlet** velocity of 7 ft/s at 80° F. If the condenser is situated at 18 ft above sea level, and the pressure drops in the circulating water system are as follows: 4 ft in inlet tunnel, 6 ft in inlet pipe and 3 ft in outlet pipe, then **sketch** the condenser and **show** its process on a ***T-s*** diagram and **find**:

a) number of tubes used, assuming similar design parameters to what was solved in class lectures.

b) the mass flow rate of the condenser cooling water if it undergoes 20° F temp. rise.

c) the pumping power, assuming 90% efficiency for pumps.

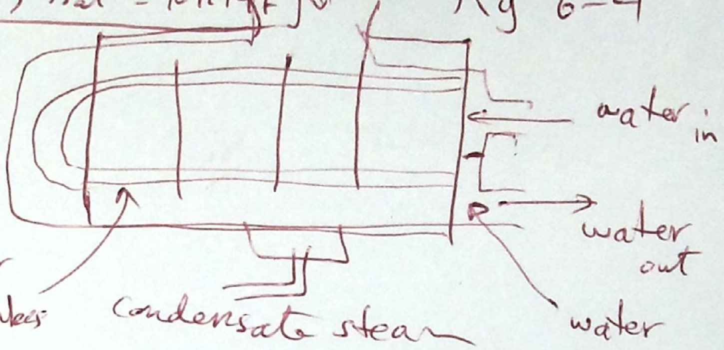
7/8"

Solution:

$\boxed{P_{cond,steam} \cong 1 \text{ psia},\ T_{sat} = 101.74°F}$

steam

Fig 6-4



If Q = 1100 MW is the heating load, then

$$Q = 1100 \times (550)(1{,}341) = 8.11 \times 10^{8} \ (\text{lb}_f\text{-ft/s}) \times \frac{3600}{778.16} = 3.75 \times 10^{9} \text{ Btu/hr}$$

$$\Delta T_{in} = T_{sat} - 80 = 101.74 - 80 = 21.74°F$$

$$\Delta T_o = TTD = 4.74°F$$

$$\Delta T_m = \frac{21.74 - 4.74}{\ln(21.74/4.74)} \cong 10°F,$$

$\boxed{\Delta T_{cooling\ water} = 20°F,\ C_{water} = 1 \text{ Btu/lb}_m\,°F,\ \dot m_w = \frac{Q}{C\,\Delta T_w}}$

$$U = C_1 C_2 C_3 C_4 \sqrt{V}\ ;\ C_1 = 263,\ C_2 = 1.04,\ C_3 = 0.58,\ C_4 = 0.85$$

$$\Rightarrow U = 263(1.04)(0.58)(0.85)\sqrt{7} = 356.8 \text{ Btu/h.ft}^2\,°F$$

(i) So, total tube surface area $= \frac{Q}{U \Delta T_m} = 859{,}448 \text{ ft}^2$

for 7/8" tubes, surface area per foot is 0.2291 ft²/ft,

so, total tubes length $= \frac{859{,}448}{0.2291} = 3.75 \times 10^{6}$ ft

$\Rightarrow$ Number of tubes $\cong \frac{3.75 \times 10^{6}}{50} = 75{,}060$ tube

- Good Luck -

(c) $\Delta P = 18 + \Sigma \Delta P = 18 + (4 + 6 + 3) = 31$ ft

Pump power $= \frac{\dot m \, \Delta P}{0.9} = \frac{1.875 \times 10^{8}(31)}{(3600)(550)(0.9)}$ ~~lbm ft / hr hr~~

~~[illegible]~~ 3290 hp | Pump Power = 2936 hp

(b) $\dot m_{cooling\ water} = \frac{3.75 \times 10^{9}}{1 \times 20} = 1.875 \times 10^{8}$ lbm/hr

≈ 2.5 MW

$$\eta_{stage} = \eta_B \, \eta_N = 0.58 \Leftarrow$$

(ii) $\eta_{stage} = \dfrac{\dot{W}}{\dot{m}\,\Delta h_s} = (0.9)(0.64) = \underline{\underline{57.8\%}}$

(c) $V_{B,opt} = V_{s,1} \cos\theta$, corresponding to $(\phi = 90^\circ)$

$= (661)\cos 25 = \underline{\underline{599.07\ ft/s}}$

which is higher than given value, i.e. the turbine is not running at max. efficiency.

(d) $\dot{W}_{th} = \dot{m}\,(\Delta h + \cancel{\Delta K.E} + \Delta P.E.)$

$$= \frac{1.04 \times 10^6 \times 25}{(1.341)\,550\ \ 3600} \ \frac{Btu}{lb_m} \times \frac{lb_m}{hr} \times \frac{hr\,(778)\,lb.ft}{s\ \ Btu}$$

$$\boxed{\dot{W}_{therm} = 7.62\ MW}$$

$\dot{W}_{actual} = \dot{W}_{therm} \times \eta_{stage} = 7.62 \times 0.578$

$= \underline{\underline{4.4\ MW}} \Leftarrow$

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Mechanical Engineering Department
Power Plants – Course # ME 0954443
Instructor: Dr. Jamil Al Asfar

2000 TR =
7.6 MW
~~7.6~~ MW

Second Exam – Dec. 2nd, 2014

Name: ......Key...... ID #:.......... .... Serial #: ______ (25 points)

Q1) (13 points) A 50% reaction steam turbine, whose 90% nozzle efficiency and 25° angle, undergoes a total of 25 Btu/lb_m enthalpy drop. The blades velocity is 420 ft/s and have: $\gamma = 22°$, V_{r1}= 332 ft/s and V_{s2}=386 ft/s . If the steam flows at 1.04×10^6 lb_m/h, **draw** the velocity triangles and find: **(i)** work done through the stage **(ii)** blade and stage efficiency **(iii)** optimal blade velocity **(iv)** work done by stage from thermodynamic, and compare with above result.

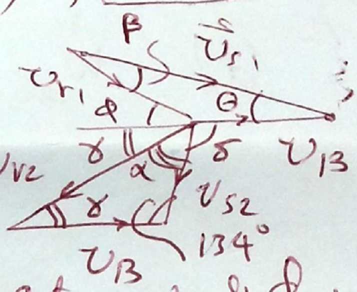
$\Delta h_{actual} = 25$ Btu/lbm

94 page
Fig. 5.14
single stage

(a) $V_B = 420$ ft/s ≈ 128 m/s , $\eta_N = 0.9$, $\theta_1 = 25°$

$V_{r1} = 332$ ft/s ≈ 101.2 m/s , $\dot{m} = 1.04 \times 10^6$ lb_m/h or 490,320 kg/hr

$V_{s2} = 386$ ft/s (117.7 m/s) , $\boxed{\gamma = 22°}$



From velocity triangles:

$V_{s1} \cos\theta = V_B + V_{r1} \cos\phi$ ... (i)

$V_{s1} \sin\theta = V_{r1} \sin\phi$ ... (ii)

Solve above two equations to get V_{s1} & ϕ.

Or, from inlet triangle: $\frac{V_B}{\sin\beta} = \frac{V_{r1}}{\sin\theta} \Rightarrow \sin\beta = \frac{V_B \sin\theta}{V_{r1}}$

$\Rightarrow \beta = 32.3° \Rightarrow \phi = \theta + \beta = 57.3°$

So, $V_{s1} = \frac{V_{r1} \sin\phi}{\sin\theta} = 661$ ft/s ≈ 201.5 m/s (not 1061.9 ft/s)

$\frac{V_{r2}}{\sin 134} = \frac{386}{\sin 22}$

From outlet triangle: $\frac{V_{s2}}{\sin\delta} = \frac{V_B}{\sin\alpha} \Rightarrow \alpha = 24°$

Then, $V_{r2} = 741.2$ ft/s

$\Rightarrow$ So, $\dot{W} = \dot{m} V_B (V_{s1} \cos\theta - V_B + V_{r2} \cos\gamma \; (- V_{s2} \cos\delta))$

But, $\boxed{1 \text{ Btu} = 778 \text{ lbf ft}}$

$\dot{W} = 1.04 \times 10^6 \frac{lbm}{hr} \frac{(420 \text{ ft/s})}{(3600)\, s/hr \; 32.2 \text{ ft/s}^2} [661 \cos 25° - 420 + 741.2 \cos 22°]$ = 287.13

$\boxed{1 \text{ hp} = 550 \text{ lbf-ft/s}}$

$\Rightarrow \dot{W} = 3.266 \times 10^6$ lbf.ft/s = ~~566.8~~ 5938.5 hp

$\Rightarrow \boxed{\dot{W} = 4.428 \text{ MW}}$

$\boxed{1 \text{ MW} = 1341 \text{ hp}}$

But, $\Delta h_{s,mov} = \frac{25/2}{0.9} = 13.89$ Btu/lbm ; = 64.7

(ii) $\eta_{blade,mov} = \frac{\dot{W}}{\dot{m}(\Delta h_{s,mov} + V_{s1}^2/2)} = \frac{3.266 \times 10^6 (32.2)}{(1.04 \times 10^6/3600)[13.89 \times 778 (32.2) + (661)^2/2]}$