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(1) Steam doesn't condense :

Assuming $P = 500 kPa = const$
$= 5 bar$

Initially steam, at 5 bar, 300°C, superheated-vap
Finally saturated vap. at 5 bar

$h_{final} = h_{g_{5bar}} = 2747.7$ kJ/K

$h_{initial} = h_{5bar, 300°C} = 3064.20$ kJ/K

$\Rightarrow Q_{to\ water} = \Delta H = m(h_{initial} - h_{final})$

$= m(3064.20 - 2747.7) = 316.5 m$

$\Delta h_{water} = h_{75} - h_{15}$ {from subcooled liq table}

$= h_{75,f} - h_{15,f}$ {from sat. table}

$= 313.94 - 62.94 = 251.00$ kJ/kg

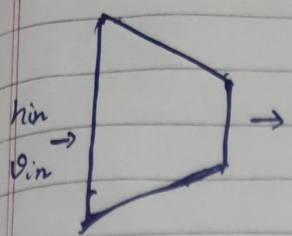
ΔH per kg $= 251.00$ kJ

Equating both the heat values; we have.

$m(316.5) = 251.00 \times 1$

$\Rightarrow m = \frac{251}{316.5} = 0.79304$ kg $\therefore \boxed{0.7930}$

(2)



Inlet: P = 10 bar {1 MPa} $\dot{m}_{in} = 0.1$ kg/s

T = 400°C

Steam

hin = 3263.88 kJ/kg

Outlet: P = 5 bar

T = 350°C

Steam

hout = 3167.65 kJ/k

We have

$$\dot{m}_{in}\left(h_{in} + \frac{v_{in}^2}{2} + gz_{in}\right) = \dot{m}_{out}\left(h_{out} + \frac{v_{out}^2}{2} + gz_{out}\right)$$

For a nozzle $\dot{m}_{in} = \dot{m}_{out}$

as total mass inside = const

& also z is same for inlet and outlet

$$\Rightarrow \dot{m}\left(h_{in} + \frac{v_{in}^2}{2} + gz\right) = \dot{m}\left(h_{out} + \frac{v_{out}^2}{2} + gz\right)$$

$$\Rightarrow h_{in} + \frac{v_{in}^2}{2} = h_{out} + \frac{v_{out}^2}{2}$$

$v_{in} <<< v_{out}$ $\Rightarrow$ can be neglected

$$\Rightarrow h_{in} = h_{out} + \frac{v_{out}^2}{2}$$

$$\Rightarrow v_{out} = \sqrt{2(h_{in} - h_{out})} = \sqrt{2(3263.88 - 3167.65) \times 10^3}$$

$$= 13.8729 \times \sqrt{1000} = 438.7026$$

$$\therefore \boxed{v_{out} = 438.7026 \text{ m/s}}$$

$\dot{m} = 0.1 \, kg/s = A_{out} v_{out} \rho$

$\Rightarrow A_{out} = \dfrac{\dot{m}}{\rho v_{out}} = \dfrac{0.1 \, v_{steam}}{438.7026} = 2.279 \times 10^{-4} \, v$

$= 2.279 \times 10^{-4} \times 0.57012 \quad m^2$

$= 1.2995 \times 10^{-4} \, m^2 = 1.2995 \, cm^2$

$\therefore \boxed{\begin{aligned} v_{out} &= 438.7026 \, m/s \\ A_{out} &= 1.2995 \, cm^2 \end{aligned}}$

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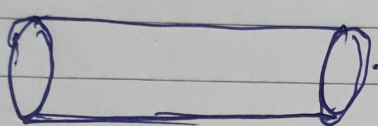
(3) $P = 15$ bar



$\rightarrow P = 2 bar$

$T = 150^\circ C$

$v_{in} = 5 \, m/s$

Here, as KE is tobe neglected

$\Rightarrow \dot{m}\left(h_{in} + \dfrac{KE_{in}}{\dot{m}} + PE\right) = \dot{m}\left(h_{out} + \dfrac{KE_{out}}{\dot{m}} + PE\right)$

$= h_{in} + \dfrac{KE_{in}}{\dot{m}} = h_{out} + \dfrac{KE_{out}}{\dot{m}}$

$\Rightarrow \boxed{h_{in} = h_{out}}$ {As we neglect KE}

Here, $\underset{\{150^\circ C\}}{T} < \underset{\{198.3^\circ C\}}{T_{sat}}$ at 15 bar {∴ subcooled liq}

$h_{in} = h = h_f = 632.15 \, kJ/k$

{As no val in subcooled table}

$\therefore h_{in} = h_{out} = 632.15 \, kJ/k$

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At 2bar

$h_f = 504.7$ kJ/k

$h_g = 2706.4$ kJ/k

$h_{fg} = 2201.7$ kJ/k

& $h = 632.15$ kJ/k

$\because$ $h_f < h < h_g$

$\Rightarrow$ Sat. liq. vap mixture

$$x = \frac{h - h_f}{h_{fg}} = \frac{632.15 - 504.7}{2201.7} = 0.057887$$

$\dot{m}$ = constant

$\Rightarrow \rho_{in} A v_{in} = \rho_{out} A v_{out}$

$\Rightarrow \frac{1}{V_{in}} \cdot \cancel{A} v_{in} = \frac{1}{V_{out}} \cancel{A} v_{out}$ { $\rho_{in} = \frac{1}{V_{in}}$, V_{in} = sp. volume, $\rho_{out} = \frac{1}{V_{out}}$ }

$\Rightarrow v_{out} = \left(\frac{V_{out}}{V_{in}}\right) v_{in}$

$= v_{in} \frac{(V_f + x V_{fg})}{(V_{f,in})} = 5 \times \left(\frac{0.001061 + 0.057887 \times 0.884969}{0.0010906}\right)$

$V_{f,out} = V_{f,2bar} = 0.001061$ m^3/kg, $V_{g,2bar} = 0.884969$ m^3/kg

$V_{f,in} = V_f$ at $150^\circ C = 0.0010906$ m^3/kg

$= 5 \times 47.94535$

$= 239.7267$ m/s

$$\boxed{\begin{aligned} \therefore v_{out} &= 239.7267 \text{ m/s} \\ x &= 0.057887 \end{aligned}}$$

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(4) $E_{in} = E_{out}$, for a turbine

$\Rightarrow Q + m\left(h_{in} + \frac{v_{in}^2}{2} + gz_i\right) = W + m\left(h_{out} + \frac{v_{out}^2}{2} + gz\right)$

$Q = 0$, & differentiating

$\Rightarrow \dot{W} = \dot{m}\left(h_{in} - h_{out} + \frac{v_{in}^2 - v_{out}^2}{2} + g(z_{in} - z_{out})\right)$

$\Rightarrow \omega = h_{in} - h_{out} + \frac{v_{in}^2}{2} = \frac{v_{in}^2}{2} - \Delta h$

{as given $v_{out} \approx 0$, $z_{in} = z_{out}$ }

h_{in}: 2000 kPa = 20 bar ~~= ... kJ/kg~~
20°C
$\Rightarrow$ Subcooled liq
{as $P_{sat} = 0.02337$ bar at 20°C}

h_{out}: 100 kPa = 1 bar, 20°C
$\Rightarrow$ Subcooled liq.

As for liquids change in v is very negligible
$\therefore \Delta h$ is very negligible
$\therefore$ we have to do from equations
{As table would give 0 difference on approximation}

$\therefore h = u + pv \qquad dh = du + pdv + vdp$
$= 0 + 0 + vdp$ {as T = const $\Rightarrow du = 0$, v = const nearly}

$\therefore \Delta h = v\,\Delta p$

$v = v_f$ at 20°C $= 0.0010017\ m^3/kg$

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$\Rightarrow \Delta h = v\,\Delta p$

$= -0.001017\ m^3/kg\ (20\ bar - 1\ bar) \times 10^2\ \frac{kPa}{bar}$

$= -1.90323\ kJ/kg.$

$w = \frac{v_{in}^2}{2} - \Delta h = \left(\frac{15^2}{2}\right) \times 10^{-3} - \Delta h$

$= 0.1125 + 1.90323$

$= 2.01573\ kJ/kg$

$P = \dot{m} \cdot w = 2 \times 2.01573$

$$\boxed{\begin{aligned} P &= 4.03146\ kW \\ w &= 2.01573\ kJ/kg \end{aligned}}$$

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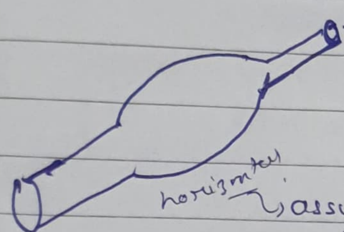
(5)



$\rightarrow d = 1cm$

$P = 100KPa = 1bar$

horizontal assumed $\{\Delta z = 0\}$

$15^\circ C$

$100KPa = 1\ bar$

$Q + w + \left(h_{in} + \frac{v_{in}^2}{2} + gz\right) m = m\left(h_{out} + \frac{v_{out}^2}{2} + gz\right)$

$\Rightarrow Q + w = m\left(h_{out} - h_{in} + \frac{V_{out}^2 - V_{in}^2}{2}\right)$

$= m\left(\Delta h + \frac{V_{out}^2 - V_{in}^2}{2}\right)$

$\because Q = 0$

$\Rightarrow w = m\left(\Delta h + \frac{v_2^2 - v_1^2}{2}\right)$

As for compressed liquid
$\Delta h = v\,\Delta p + \Delta u$
$\because \Delta p = 0$ {1 bar − 1 bar} & $\Delta u = 0$ given
$\Rightarrow$ here, $\Delta h = 0$?

$\therefore Q + w = w = 0 + \left(\frac{V_{out}^2 - V_{in}^2}{2}\right) m$

$$\boxed{w = \frac{m v_{out}^2}{2}}$$

{$v_{in} \approx 0$ as finally short pipe}

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$$\boxed{W = \frac{m v_{out}^2}{2}}$$

$\dot{m} = \rho A v = \dfrac{A v}{\nu}$ { where v = velocity, ν = specific volume }

$P = \dfrac{dW}{dt} = \dfrac{v_{out}^2}{2} \cdot \dfrac{dm}{dt} = \dfrac{v_{out}^2}{2} \cdot \dfrac{A v_{out}}{\nu}$
{Power}

$$\Rightarrow v_{out}^3 \cdot \frac{A}{2\nu} = P$$

$$\Rightarrow v_{out} = \left(\frac{2P\nu}{A}\right)^{1/3} = \left(\frac{2 \times 0.0010008 \times 10^3}{\frac{\pi}{4}(1 \times 10^{-2})^2}\right)^{1/3} = 29.498 \text{ m/s}$$

{ $\nu = 0.0010008$ m³/kg, $P = 1\text{kW} = 10^3$ W }

$$\dot{m} = \frac{A v}{\nu} = \left(\frac{\pi d^2}{4}\right) \cdot \frac{29.498}{0.0010008} = 2.31495$$

$\therefore$ $\boxed{\begin{aligned} v &= 29.498 \text{ m/s} \\ \dot{m} &= 2.31495 \text{ kg/s} \end{aligned}}$