6.8 Steam Condenser Design.

The common type of surface steam condenser is shall and tube, see figure (6.9). It's made from steel drum called shall. Inside shall there is a bundle of tubes. The steam flow through shall and cooling water flow inside the bundle of tubes. Heat transfer from steam to cooling water across the surface area of the tubes, as illustrated in figure (6.10.a). The design of condenser may complicate by using multi-pass of cooling water tubes, and also by adding baffles inside shall to increase the flow disturbance, this will improve the heat transfer rate through the condenser.

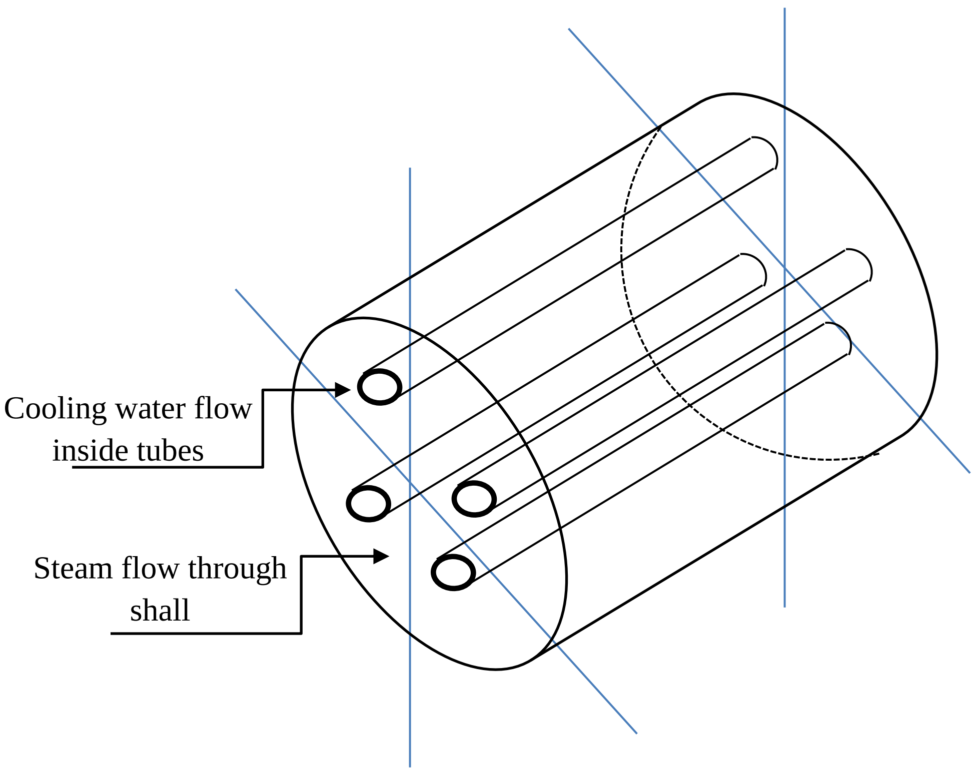


Figure (6.9): Section inside shall and tube, one pass steam condenser.

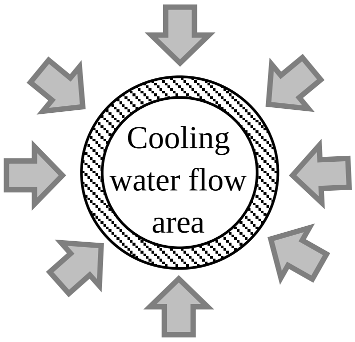


Figure (6.10.a): Heat transfer from the steam in shall to cooling water inside the tube.

Figure (6.10.b) illustrates the cross-sectional area of tube in which the cooling water flow inside it, and the surface area of tube that the heat flow across it from steam (outside in shall) to cooling water inside bundle of tubes in shall and tube heat exchanger. Wall thickness is the difference between outer and inner diameter of tube.

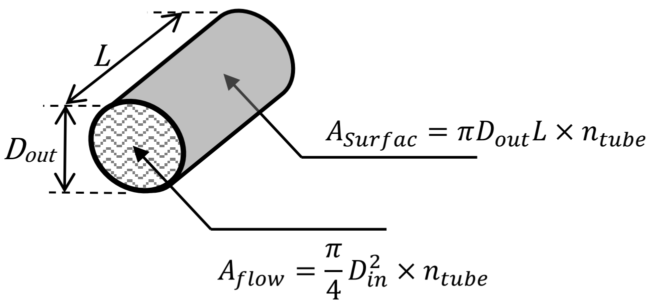


Figure (6.10.b): Surface area and cross section area of flow for tube.

To reduce the length of shall and tube heat exchanger, multi-pass rather than single pass exchanger is used in steam condenser. Where, mass flow rate of cooling water can be increased by increasing the number of tubes in the pass. Moreover, the heat transfer area increased by adding another pass in shall.

$m_w^o = A_{flow} \times V_w \times \rho_w$

Example (6.6) find the surface area required in a surface steam condenser dealing with 30,000 kg/h of steam with quality of 0.9 at 0.04 bar absolute pressure. The cooling water enters the condenser at 15°C and leaves at 25°C. Assume the overall heat transfer coefficient 3000 W/m^2.°C. This condenser has two water passes composed of tubes of 2 cm outside and 1.2 mm thick with water speed of 1.5 m/s. Determine the number of tubes in each pass and the length of each tube.

Solution: Given; $m_s^o = 30{,}000\ kg/h; x = 0.9;\ P_{abs.} = 0.04\ bar;$
$T_{w,in} = 15°C;\ T_{w,out} = 25°C; U = 3000\ W/m^2.°C; two\ pass;\ D_{out} = 2\ cm;$

$thick = 1.2\ mm; V_w = 1.5\ m/s$

$@P_{abs.} 0.04\ bar \rightarrow T_{saturated} = 29°C;\ v_f = 0.001002\ kg/m^3;\ h_f = 121.39$

$and\ \ h_g = 2553.7$

$h = h_f + x(h_g - h_f)\ \rightarrow h - h_f = x(h_g - h_f) = 0.9(2553.7 - 121.39)$

$h - h_f = 2189\ \ kj/kg$

$Q_{lost} = Q_{gained}$

$m_s^o \times (h - h_f) = m_w^o \times C_{pw} \times (T_{w,out} - T_{w,in})$

$30{,}000 \times [2189 \times 10^3] = m_w^o \times (4.2 \times 10^3) \times (25 - 15)$

$m_w^o = \frac{65{,}670 \times 10^6}{42 \times 10^3} \rightarrow m_w^o = 1563.571 \times 10^3\ \ kg/h\ \ of\ cooling\ water$

$m_w^o = \frac{1563.571 \times 10^3}{3600} = 434.3254\ \ kg/s\ \ of\ cooling\ water$

$Q_{lost} = \frac{30{,}000}{3600} \times (2189) = 18241.7\ kW$

Mean water temperature can be estimated as follows:

$T_{mean} = \frac{T_{w,out} + T_{w,in}}{2} = \frac{25+15}{2} = 20°C$

From saturated steam tables: $@T_{mean} = 20°C \rightarrow v_f = 0.001002\ \ kg/m^3$

$\rho_w = \frac{1}{v_f} = \frac{1}{0.001002} = 998\ \ kg/m^3$

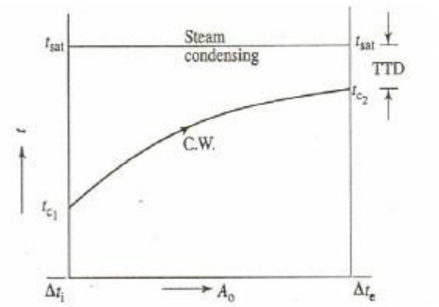
$m_w^o = A_{flow} \times V_w \times \rho_w \rightarrow A_{flow} = \frac{m_w^o}{V_w \times \rho_w} = \frac{434.3254}{1.5 \times 998} = 0.2901\ m^2$

$D_{out} = D_{in} + 2 \times thick \rightarrow D_{in} = D_{out} - 2 \times thick = 2 - 2 \times \frac{1.2}{10}$

$D_{in} = 1.76\ cm$

But, $A_{flow} = \frac{\pi}{4} \times D_{in}^2 \times n_{tube} \rightarrow n_{tube} = \frac{4 \times A_{flow}}{\pi \times D_{in}^2} = \frac{4 \times 0.2901}{\pi \times \left(\frac{1.76}{100}\right)^2}$

$n_{tube} = 1192.428 \approx 1193\ tube$



Temperature Profile through steam condenser.

$LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln\frac{\Delta T_1}{\Delta T_2}} = \frac{(29-15)-(29-25)}{\ln\frac{(29-15)}{(29-25)}} = 8°C$

$Q_{lost} = Q_{gained} = Q = 18241.7\ kW$

$Q = U \times A_{surface} \times LMTD \rightarrow A_{surface} = \frac{Q}{U \times LMTD} = \frac{18241.7\ \times 10^3}{3000 \times 8}$

$$A_{surface} = 760.07\ m^2$$

$$A_{surface} = (\pi \times D_{out} \times L_{tube} \times n_{tube}) \times pass$$

$$L_{tube} = \frac{A_{surface}}{\pi \times D_{out} \times n_{tube} \times pass} = \frac{760.07}{\pi \times (2/100) \times 1193 \times 2}$$

$$L_{tube} = 5.07\ m$$