

**Thermodynamics**  
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**Lecture - 34**  
**Tutorial Problem - Part 7**

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$Q = m C_p \Delta T$        $Q = m C_v \Delta T$        $f = 1000 \text{ kg/hr}$   
 $C_p = \frac{1}{m} \frac{dH}{dT}$        $C_v = \frac{1}{m} \frac{dU}{dT}$        $v = \frac{1}{f} = 0.001 \text{ m}^3/\text{kg}$   
 $C = C_p - C_v$        $H = U + pV$        $Q = m \Delta h_{12}$   
 $h = u + pv$

6. It is desired to melt aluminium from a solid block at 15 °C. The specific heats of solid and liquid aluminium are, 0.9 kJ/kg.K and 1.11 kJ/kg.K, respectively, and the latent heat is 390 kJ/kg. The density in the molten state is 2400 kg/m<sup>3</sup> and the final temperature is 700 °C. The melting point of aluminium is 660 °C. Determine the mass of aluminium that can be melted per hour, if the power rating of the furnace is 217 MW and its efficiency is 70%.

$Q = 217 \text{ MW}$   
 $t = 1 \text{ h} = 3600 \text{ s}$   
 $Q = \dot{Q} \times t = 217 \times 10^6 \times 3600 \text{ J}$   
 $Q = m C_s \Delta T + m \Delta h_{12} + m C_l \Delta T$

15°C 





Figure 1.

$m = \frac{Q}{C_{solid} \Delta T_{solid} + \Delta h_{12} + C_{liquid} \Delta T_{liquid}}$        $f = 2400 \frac{\text{kg}}{\text{m}^3}$

$= \frac{317 \times 10^6 \times 3600}{0.9 \frac{\text{kJ}}{\text{kgK}} (660-15) + 390 \frac{\text{kJ}}{\text{kg}} + 1.11 \frac{\text{kJ}}{\text{kgK}} (700-660)}$

$m_{ideal} = \frac{317 \times 10^6 \times 3600 \times 10^{-3}}{580.5 + 390 + 44.4} = 1.12 \times 10^6 \text{ kg}$

$\eta = 70\%$   
 $m_{actual} = \eta \times m_{ideal}$   
 $= 0.7 \times 1.12 \times 10^6$   
 $m_{actual} = 787 \times 10^3 \text{ kg in an hour}$





### Solution of the problem given in Fig.1:

The solid aluminium block at 15 °C is heated. As the temperature reaches 660 °C, the block starts melting. During melting, the temperature remains constant. Heating is continued till the temperature of liquid aluminium reaches 700°C. So the heat supplied is used to increase the temperature of solid aluminium block from 15 °C to 660 °C, melt aluminium, and then increase the temperature of liquid aluminium from 660 °C to 700 °C.

$$\dot{Q} = 217 \text{ MW}, \quad t = 1 \text{ h} = 3600 \text{ s}$$

Hence, total amount of heat transferred,  $Q = \dot{Q} \times t = 217 \times 10^6 \times 3600 \text{ J}$ .

For solids or liquids, the volume is small compared to the gas if we consider equal mass of each, because the density of solids or liquids is significantly larger than gas.

The expression for specific enthalpy is,  $h = u + pv$ . Since  $v$  is very small for a solid or liquid,  $h \approx u$ . We also know that,  $C_p = \frac{1}{m} \frac{\Delta H}{\Delta T}$  and  $C_v = \frac{1}{m} \frac{\Delta U}{\Delta T}$ . Since  $h \approx u$ ,  $C_p \approx C_v = C$  for a solid or a liquid.

The heat supplied can be expressed mathematically as,

$$Q = mC_{\text{solid}}\Delta T + m\Delta h_{\text{latent heat}} + mC_{\text{liquid}}\Delta T$$

Hence,

$$m = \frac{Q}{C_{\text{solid}}\Delta T + \Delta h_{\text{latent heat}} + C_{\text{liquid}}\Delta T} = \frac{217 \times 10^6 \times 3600 \times 10^{-3} \text{ kJ}}{0.9 \frac{\text{kJ}}{\text{kg}\cdot\text{K}} \times (660 - 15)\text{K} + 390 \frac{\text{kJ}}{\text{kg}} + 1.11 \frac{\text{kJ}}{\text{kg}\cdot\text{K}} \times (700 - 660)\text{K}} = 769.7 \text{ kg}$$

This is the mass of aluminium we can melt if all the heat supplied goes into heating and melting the aluminium.

But,  $\eta_{furnace} = 70\%$ . It means 70% of heat goes into melting aluminium. The remaining is lost. Hence, the actual amount of molten aluminium is  $m_{actual} = \eta_{furnace}m = 538.8 \text{ kg}$  in an hour.