Steam Nozzles

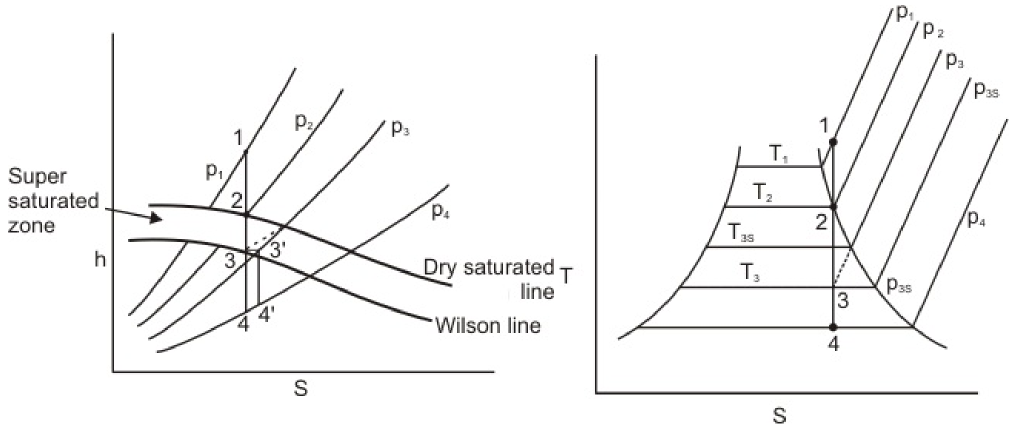

Figure 21.1 Super Saturated Expansion of Steam in a Nozzle

- The process 1-2 is the isentropic expansion. The change of phase will begin to occur at point 2
- vapour continues to expand in a dry state
- Steam remains in this unnatural superheated state untit its density is about eight times that of the saturated vapour density at the same pressure
- When this limit is reached, the steam will suddenly condense
- Point 3 is achieved by extension of the curvature of constant pressure line p_3 from the superheated region which strikes the vertical expansion line at 3 and through which Wilson line also passes. The point 3 corresponds to a metastable equilibrium state of the vapour.
- The process 2-3 shows expansion under super-saturation condition which is not in thermal equilibrium
- It is also called under cooling
- At any pressure between p_2 and p_3 i.e., within the superheated zone, the temperature of the vapous is lower than the saturation temperature corresponding to that pressure
- Since at 3, the limit of supersaturation is reached, the steam will now condense instantaneously to its normal state at the constant pressure, and constant enthalpy which is shown by the horizontal line $33'$ where $3'$ is on normal wet area pressure line of the same pressure p_3.
- $3' - 4'$ is again isentropic, expansion in thermal equilibrium.
- To be noted that 4 and $4'$ are on the same pressure line.

Thus the effect of supersaturation is to reduce the enthalpy drop slightly during the expansion and consequently a corresponding reduction in final velocity. The final dryness fraction and entropy are also increased and the measured discharge is greater than that theoretically calculated.

Degree of super heat = $\frac{p_3}{p_{3s}}$

p_3 = limiting saturation pressure

P_{3s} = saturation pressure at temperature T_3 shown on T-s diagram

degree of undercooling - T_{3s} - T_3

T_{3s} is the saturation temperature at p_3

T_3 = Supersaturated steam temperature at point 3 which is the limit of supersaturation.

$$\frac{\dot{m}}{A_2} = \sqrt{\frac{2n}{n-1}\cdot\frac{p_1}{v_1}\left[\left(\frac{2}{n+1}\right)^{\frac{n}{n-1}\cdot\frac{2}{n}} - \left(\frac{2}{n+1}\right)^{\frac{n}{n-1}\cdot\frac{n+1}{n}}\right]} \qquad (21.1)$$

$$\frac{\dot{m}}{A_2} = \sqrt{\frac{2n}{n-1}\cdot\frac{p_1}{v_1}\left[\left(\frac{2}{n+1}\right)^{\frac{2}{n-1}} - \left(\frac{2}{n+1}\right)^{\frac{n+1}{n-1}}\right]} \qquad (21.2)$$

Supersaturated vapour behaves like supersaturated steam and the index to expansion, $n = 1.3$