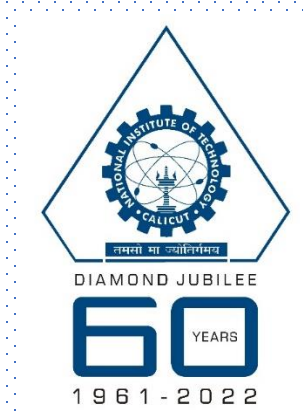


Measurement of steam quality



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THROTTLING CALORIMETER

In the throttling calorimeter, a sample of wet steam of mass **m** and at pressure **p₁** is taken from the steam main through a perforated sampling tube (Fig. 9.23).

Then it is throttled by the partially-opened valve (or orifice) to a pressure **p₂**, measured by mercury manometer, and temperature **t₂**, so that after throttling the steam is in the superheated region.

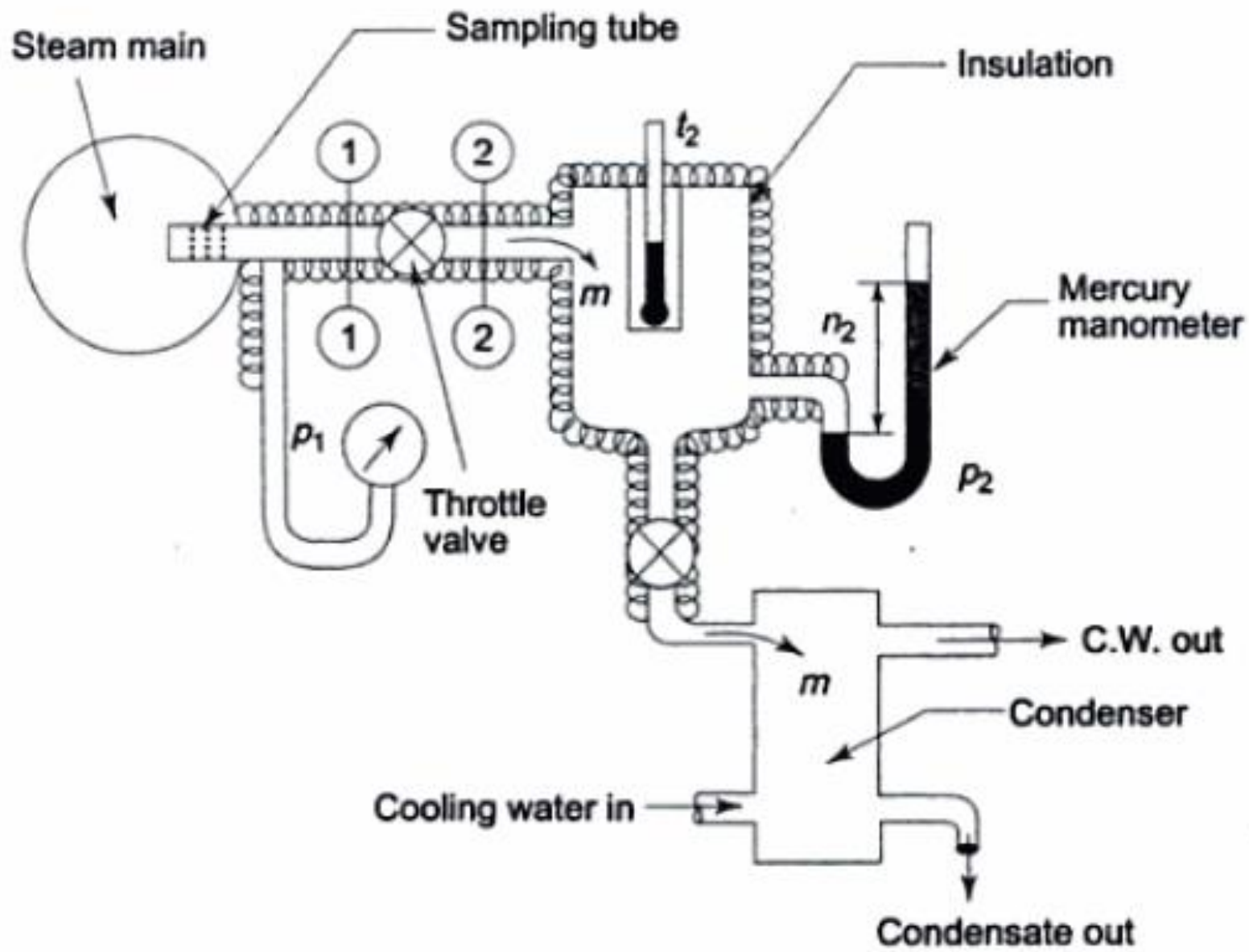


Fig. 9.23 *Throttling calorimeter*

The process is shown on the T - s and h - s diagrams in Fig. 9.24.

The steady flow energy equation gives **the enthalpy after throttling as equal to enthalpy before throttling.**

The initial and final equilibrium states 1 and 2 are joined by a dotted line since **throttling is irreversible** (adiabatic but not isentropic) and the intermediate states are non-equilibrium states not describable by thermodynamic coordinates.

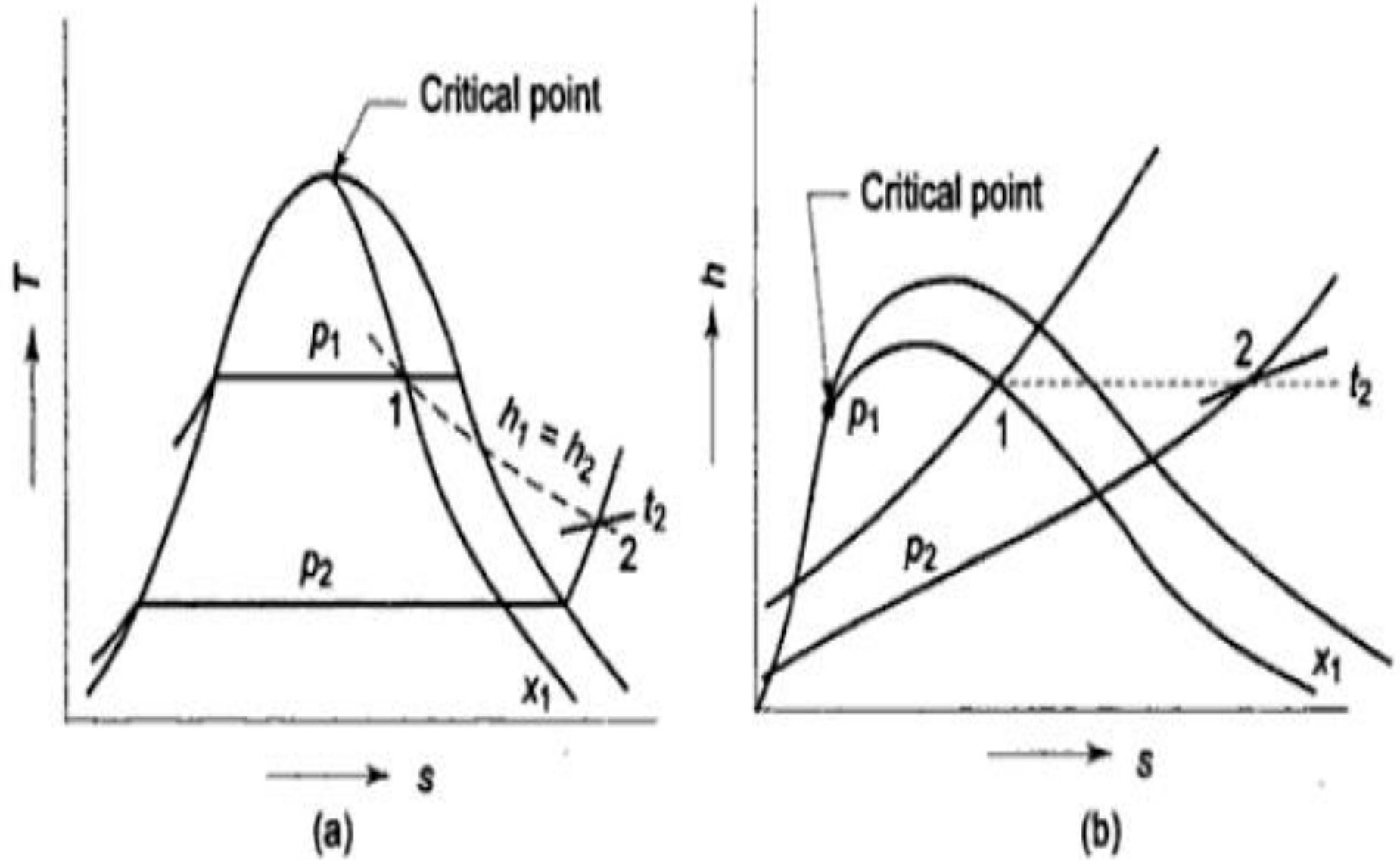


Fig. 9.24 *Throttling process on $T-s$ and $h-s$ plots*

The initial state (wet) is given by p_1 and x_1 , and the final state by P_2 and t_2 (superheated).

since

$$h_1 = h_2$$

$$h_{fp1} + x_1 h_{fgp1} = h_2$$

or

$$x_1 = \frac{h_2 - h_{fp1}}{h_{fgp1}}$$

With p_2 and t_2 being known, h_2 can be found out from **the superheated steam table**.

The values of h_f and h_{fg} are taken **from the saturated steam table** corresponding to pressure p_1 .

Therefore, the quality of the wet steam x_1 can be calculated.

COMBINED SEPARATING AND THROTTLING CALORIMETER

When the steam is very wet and the pressure after throttling is not low enough to take the steam to the superheated region, then a combined *separating* and *throttling calorimeter* is used for the measurement of quality.

Steam from the main is first passed through a separator (Fig. 9.26).

In separator some part of the moisture separates out due to the sudden change in direction and falls by gravity.

The partially dry vapour is then throttled and taken to the superheated region.

In Fig. 9.27, **process 1-2 represents the moisture separation** from the wet sample of steam at constant pressure **p1** and process 2-3 represents throttling to pressure **p3**•

With **p3** and **t3** being measured, **h3** can be found out from the *superheated steam table*.

Now,

$$h_3 = h_2 = h_{fp1} + x_2 h_{fgp1}$$

$$h_3 = h_2 = h_{fpl} + x_2 h_{fgpl}$$

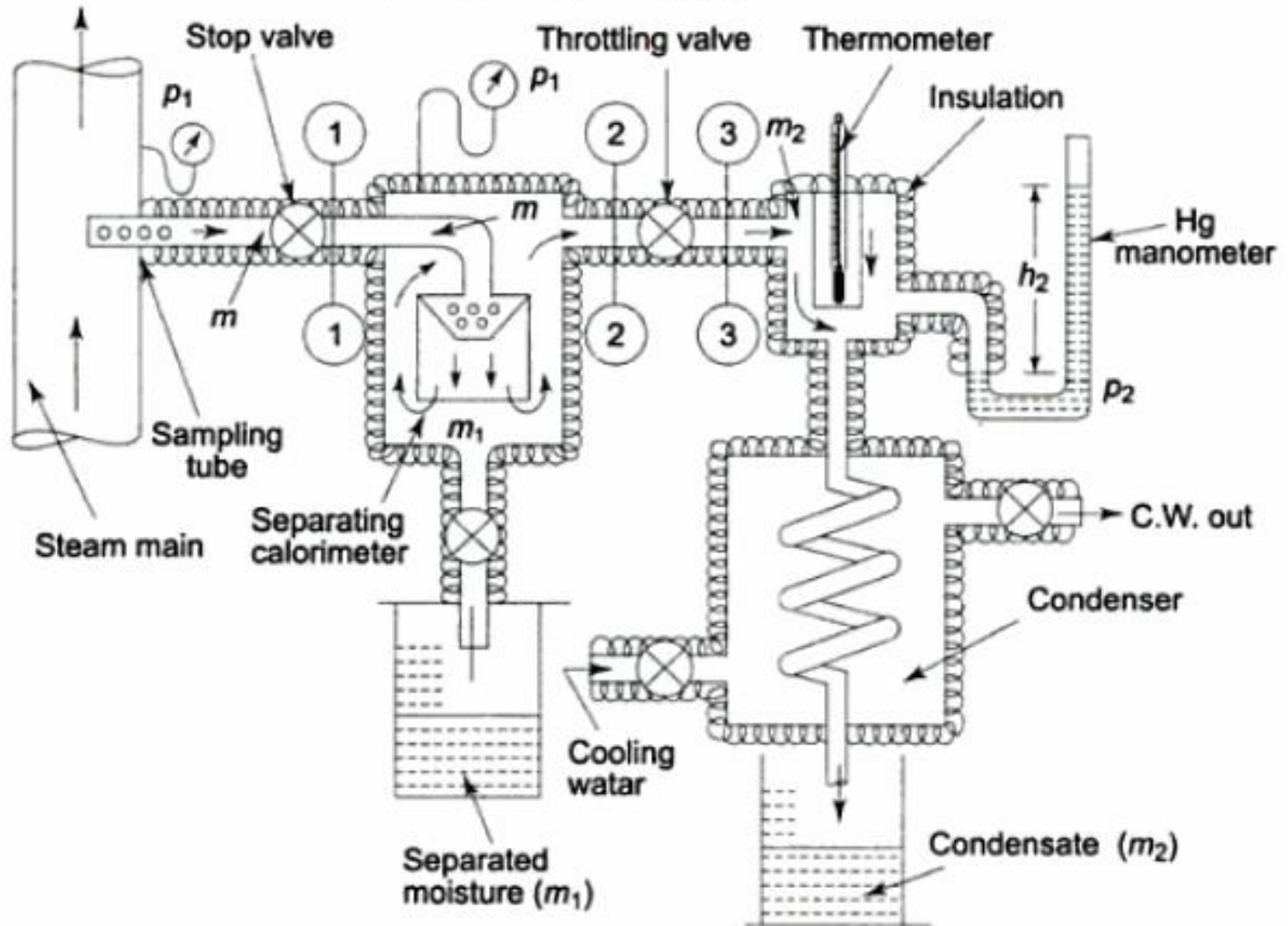


Fig. 9.26 *Separating and throttling calorimeter*

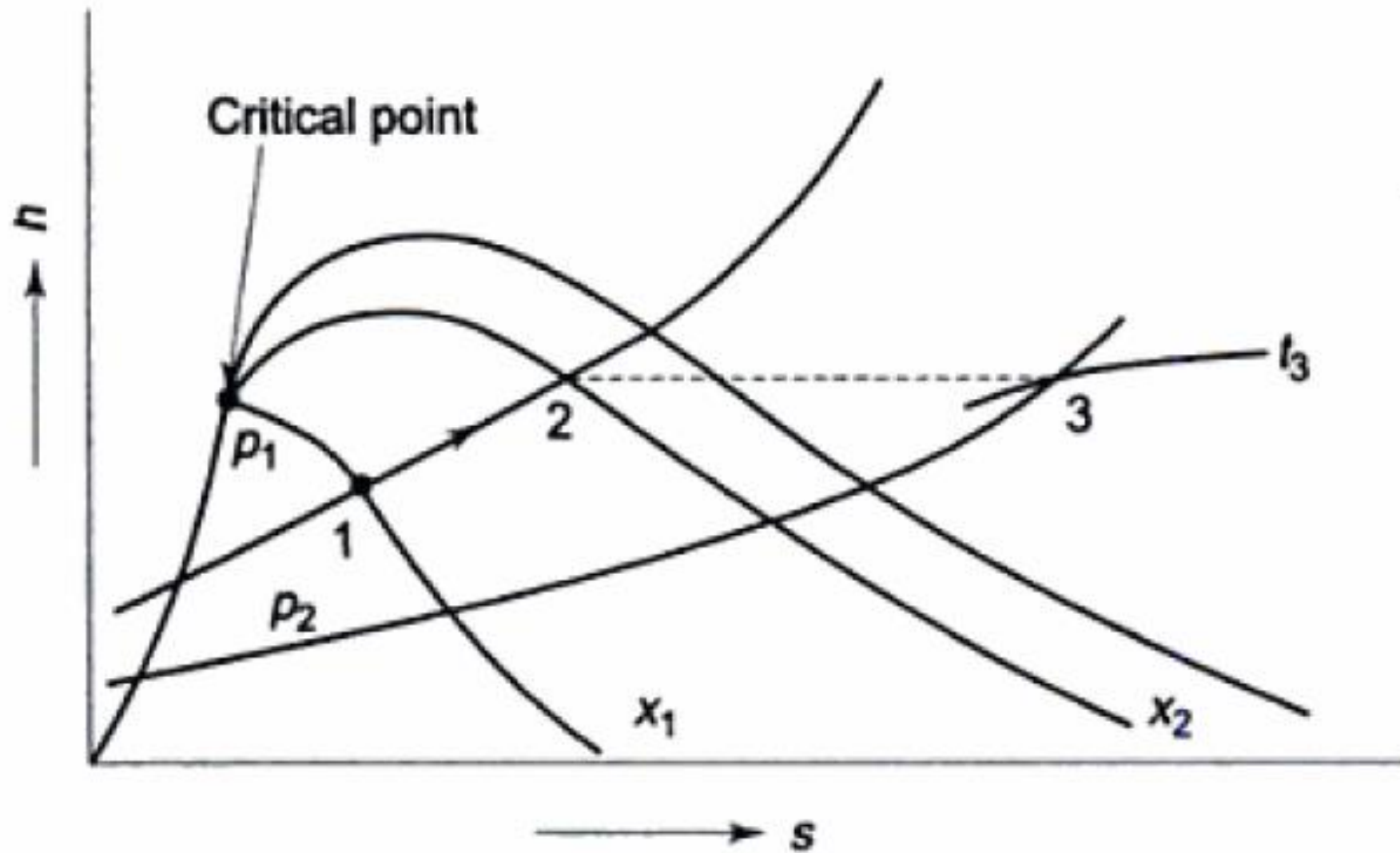


Fig. 9.27 *Separating and throttling processes on h - s plot*

Therefore, x_2 , the quality of steam after partial moisture separation, can be evaluated.

If m kg of steam is taken through the sampling tube in t secs, m_1 kg of it is separated, and m_2 kg is throttled and then condensed to water and collected, then

$m = m_1 + m_2$, and at state 2, the mass of dry vapour will be $x_2 m_2$.

Therefore, the quality of the sample of steam at state 1, x_1 is given by

$$\begin{aligned} x_1 &= \frac{\text{mass of dry vapour at state 1}}{\text{mass of liquid-vapour mixture at state 1}} \\ &= \frac{x_2 m_2}{m_1 + m_2} \end{aligned}$$

ELECTRIC CALORIMETER

The quality of wet steam can also be measured by an *electric calorimeter* (Fig. 9.28).

The sample of steam is passed in steady flow through an electric heater, as shown.

The electrical energy input Q should be sufficient to take the steam to the superheated region where pressure p_2 and temperature t_2 are measured.

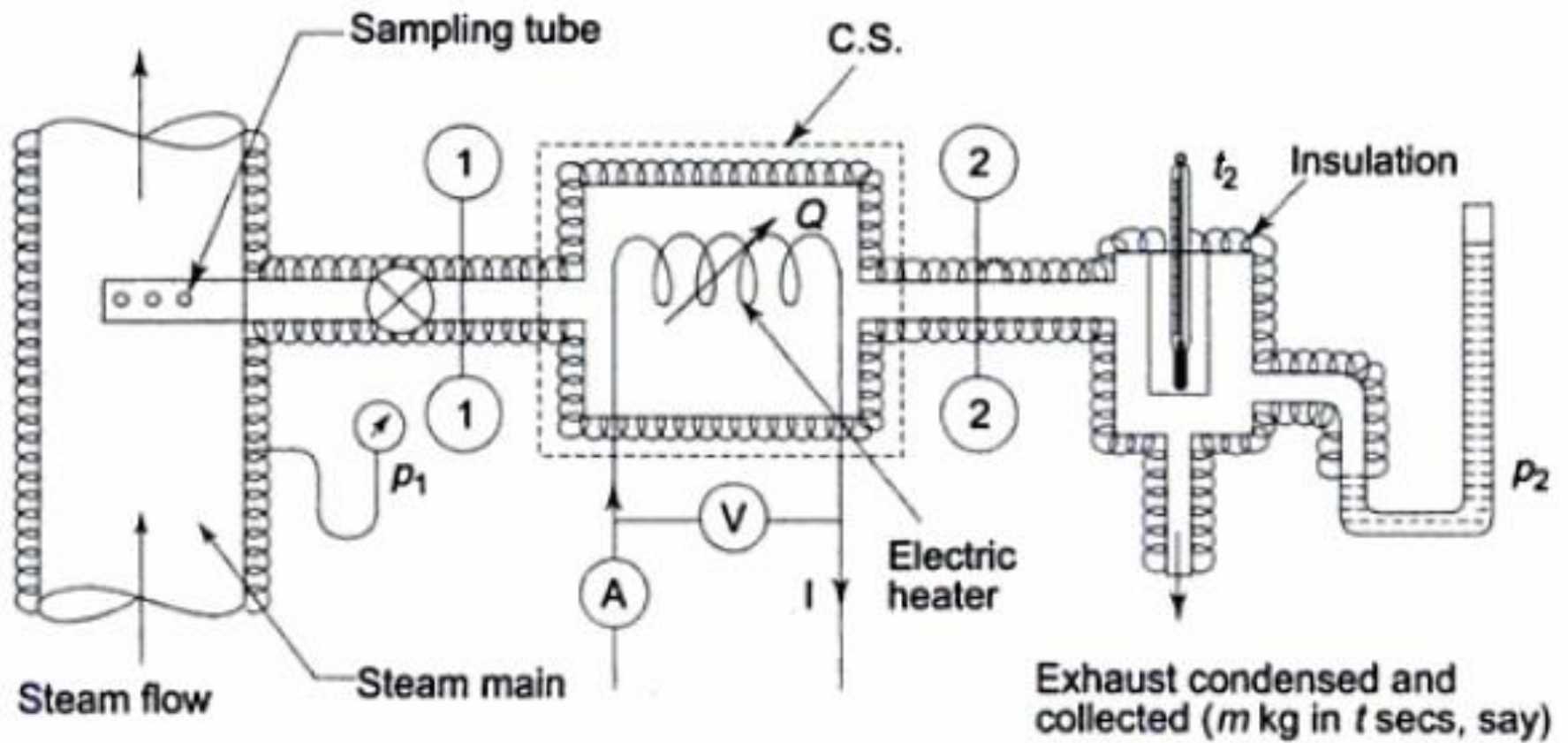


Fig. 9.28 *Electrical calorimeter*

If I is the current flowing through the heater in amperes and V is the voltage across the coil, then at steady state $Q = VI \times 10^{-3} \text{ kW}$.

If m is the mass of steam taken in t seconds under steady flow condition, then the steady flow energy equation for the heater (as control volume) gives

$$w_1 h_1 + Q = w_1 h_2$$

where w_1 is the steam flow rate in kg/s $\left(w_1 = \frac{m}{t} \text{ kg/s} \right)$

$$\therefore h_1 + \frac{Q}{w_1} = h_2$$

With h_2 , Q and w_1 being known, h_1 can be computed. Now

$$h_1 = h_{fp1} + x_1 h_{fgp1}$$

Hence x_1 can be evaluated.