Solution $\eta_{\text{plant}} = \eta_{\text{Boiler}} \times \eta_{\text{Turbine(mech)}} \times \eta_{\text{Generator}} \times \eta_{\text{Cycle}} \times \eta_{\text{Auxiliaries}}$

$$\therefore \quad \eta_{\text{Auxiliaries}} = \frac{0.33}{0.97 \times 0.95 \times 0.92 \times 0.42} = 0.9268$$

$$1 - 0.9268 = 0.0732$$

or 7.32% of total electricity generated is consumed by the auxiliaries.

Example 2.5 A steam generator comprises a boiler, a superheater, an economiser and an air preheater. The feedwater enters the economiser at 140 °C and leaves as saturated liquid. Air is preheated from a temperature of 25 °C to 250 °C. Steam leaves the boiler drum at 60 bar, 0.98 dry and leaves the superheater at 450 °C. When using coal with a calorific value of 25.2 MJ/kg, the rate of evaporation is 8.5 kg steam per kg coal and the air fuel ratio is 15 : 1 by mass. Neglecting heat losses and pressure drops, estimate the heat transfer per kg fuel in each component and the efficiency of the steam generator. What are the percentages of the total heat absorption taking place in the economiser, boiler and the superheater, respectively? Assume c_p of air and water as 1.005 and 4.2 kJ/kg K, respectively.

Solution With reference to Fig. E2.5, $h_1 = 140 \times 4.2 = 588$ kJ/kg

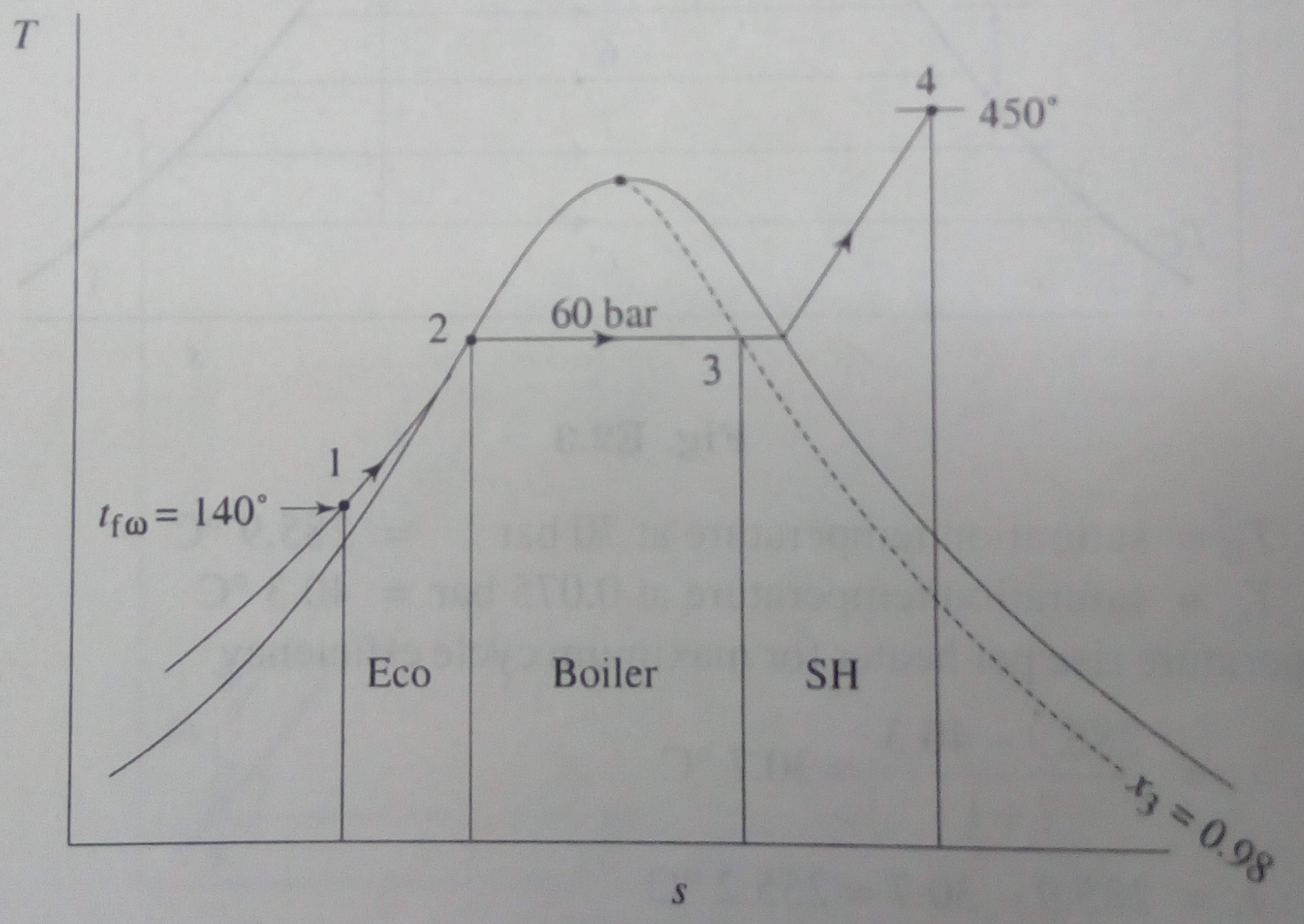

Fig. E2.5

$h_f = 1213.35$ kJ/kg, $h_{fg} = 1571.0$ (at 60 bar)

$h_4 = 3301.8$ kJ/kg,

$h_3 = 1213.35 + 0.98 \times 1571.0 = 2752.93$ kJ/kg

$$\eta_{\text{St.gen}} = \frac{w_s (h_4 - h_1)}{w_f \times \text{C.V.}} = \frac{8.5 \times 2713.8}{25.2 \times 1000} = 0.9154 \quad \text{or} \quad 91.54\%$$

Heat transfer in the economiser

$$= \frac{w_s (h_2 - h_1)}{w_f} = 8.5 \times 625.35 \times 10^{-3} = 5.3155 \text{ MJ/kg}$$

Heat transfer in the boiler

$$= \frac{w_s (h_3 - h_2)}{w_f} = 8.5 \times 1539.58 \times 10^{-3} = 13.086 \text{ MJ/kg}$$

Heat transfer in the superheater

$$= \frac{w_s (h_4 - h_3)}{w_f} = 8.5 \times 548.87 \times 10^{-3} = 4.665 \text{ MJ/kg}$$

Heat transfer in the air pre-heater

$$= \frac{w_a c_{p_a} (t_2 - t_1)}{w_f} = 15 \times 1.005 \times (250 - 25) \times 10^{-3} = 3.392 \text{ MJ/kg}$$

Percentage of total heat absorbed in the economiser

$$= \frac{h_2 - h_1}{h_4 - h_1} \times 100 = \frac{625.35}{2713.8} \times 100 = 23.04\%$$

Percentage of total heat absorbed in the boiler

$$= \frac{h_3 - h_2}{h_4 - h_1} \times 100 = \frac{1539.58}{2713.8} \times 100 = 56.73\%$$

Percentage of total heat absorbed in the superheater

$$= \frac{h_4 - h_3}{h_4 - h_1} \times 100 = \frac{548.87}{2713.8} \times 100 = 20.23\%$$

Eample 2.6 Steam at 150 bar, 550 °C is expanded in an h.p. turbine to 20 bar when it is reheated to 500 °C and expanded in i.p. and 1.p. turbines to condenser pressure of 0.075 bar. There are five feedwater heaters, one extraction from h.p. turbine at 50 bar, 3 from i.p. turbine at 10 bar, 5 bar and 3 bar, and one from 1.p. turbine at 1.5 bar. The middle heater is the deaerator and all others are closed heaters. Assuming ideal conditions, determine (a) the cycle efficiency, (b) the feedwater temperature at inlet to the steam generator, (c) the steam rate, (d) the heat rate, (e) the quality of steam at turbine exhaust, and (f) the power output if the steam flow rate is 300 t/h. Take TTD = 0 for all the heaters.

Solution With reference to Fig. E2.6,

$h_1 = 3448.6$ kJ/kg, $s_1 = s_2 = s_3 = 6.5199$ kJ/kg K

$h_4 = 3467.6$ kJ/kg, $s_4 = s_5 = s_6 = s_7 = s_8 = s_9 = 7.4317$ kJ/kg K

$t_2 = 370$ °C, $h_2 = 3112$ kJ/kg

$t_3 = 245$ °C, $h_3 = 2890$ kJ/kg

$t_5 = 400$ °C, $h_5 = 3250$ kJ/kg

$t_6 = 300$ °C, $h_6 = 3050$ kJ/kg

$t_7 = 225$ °C, $h_7 = 2930$ kJ/kg

$t_8 = 160$ °C, $h_8 = 2790$ kJ/kg

$$7.4317 = 0.5764 + x_9 \times 7.6751$$

$x_9 = 0.8932$

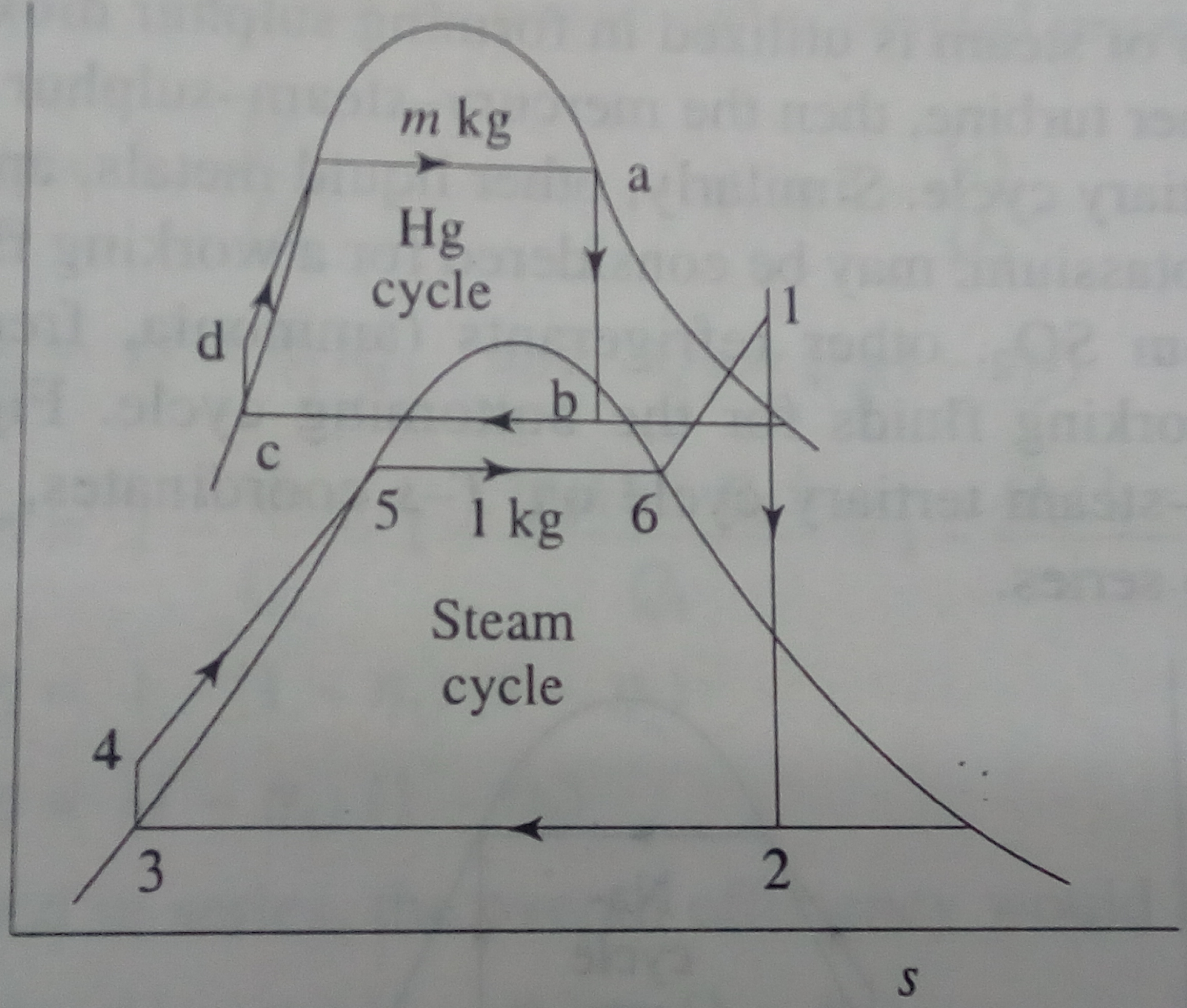

Fig. 3.3 *T–s* diagram of mercury-steam binary cycle

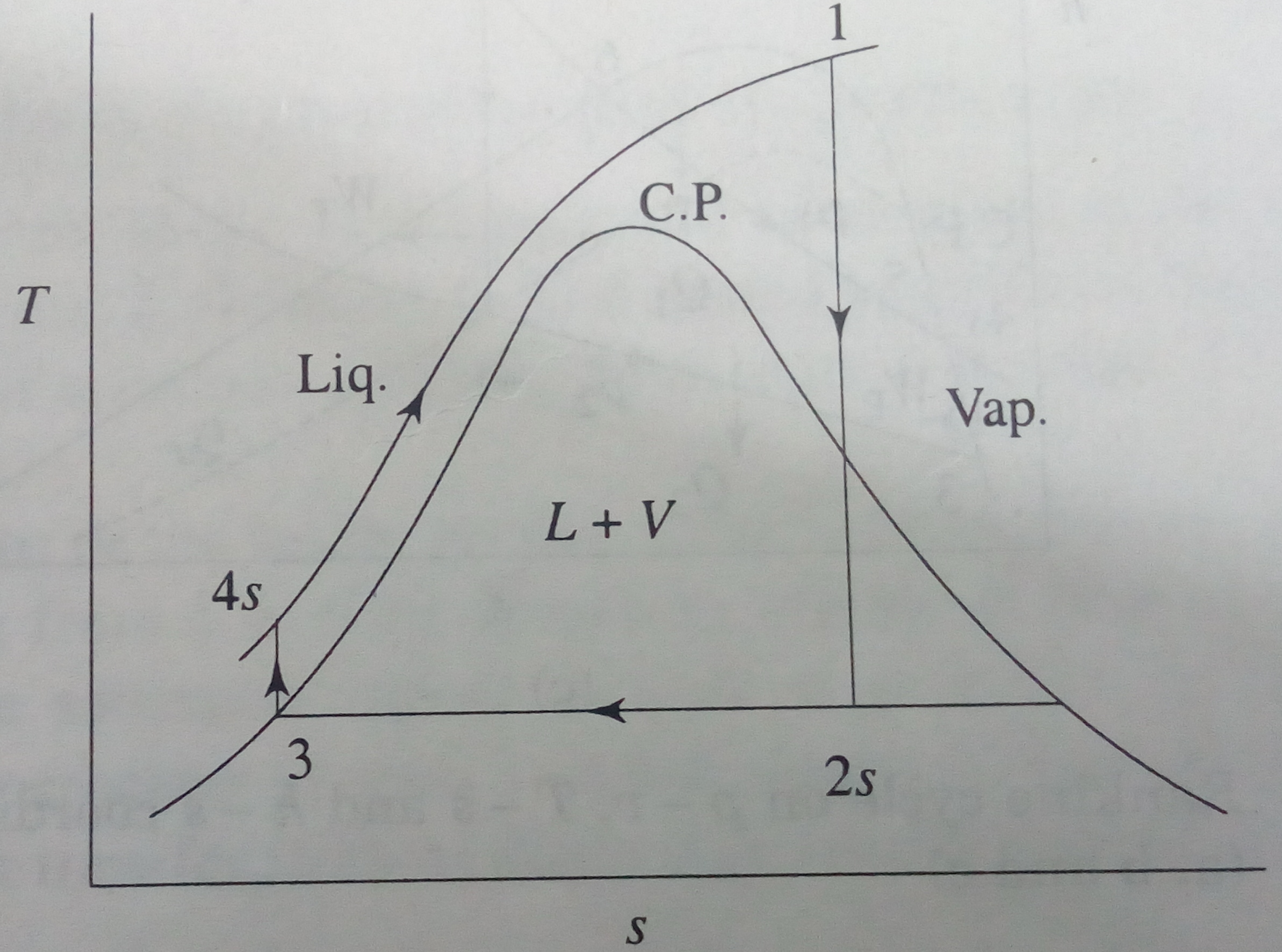

Fig. 2.5 Rankine cycle with supercritical boiler pressure