Water Side Dynamics of an OTSG
SAIT Power Engineering Students
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Homework assignment: Answers

A small OTSG has 150°C feed water, and generates wet steam at 7,000 kPaa. Feed water rate is 70,000 kg/hr, Heat input from firing is 125 GJ/hr. Tube volume is 9 m^3, with 4 tube passes.

1) What is the water inlet enthalpy? What is the enthalpy of boiling water (0% quality), and saturated steam (100% quality). Sketch on a graph of enthalpy vs total tube volume. Use steam tables.

Inlet	T	150 C	, H =	***632*** kJ/kg	from steam tables
Sat Liq	P	7000 kPaa	, H =	***1312*** kJ/kg	from steam tables
Sat Vap	P	7000 kPaa	, H =	***2760*** kJ/kg	from steam tables

2) What is outlet steam quality? Assume the heat is added uniformly along the tube. Draw the operating line.

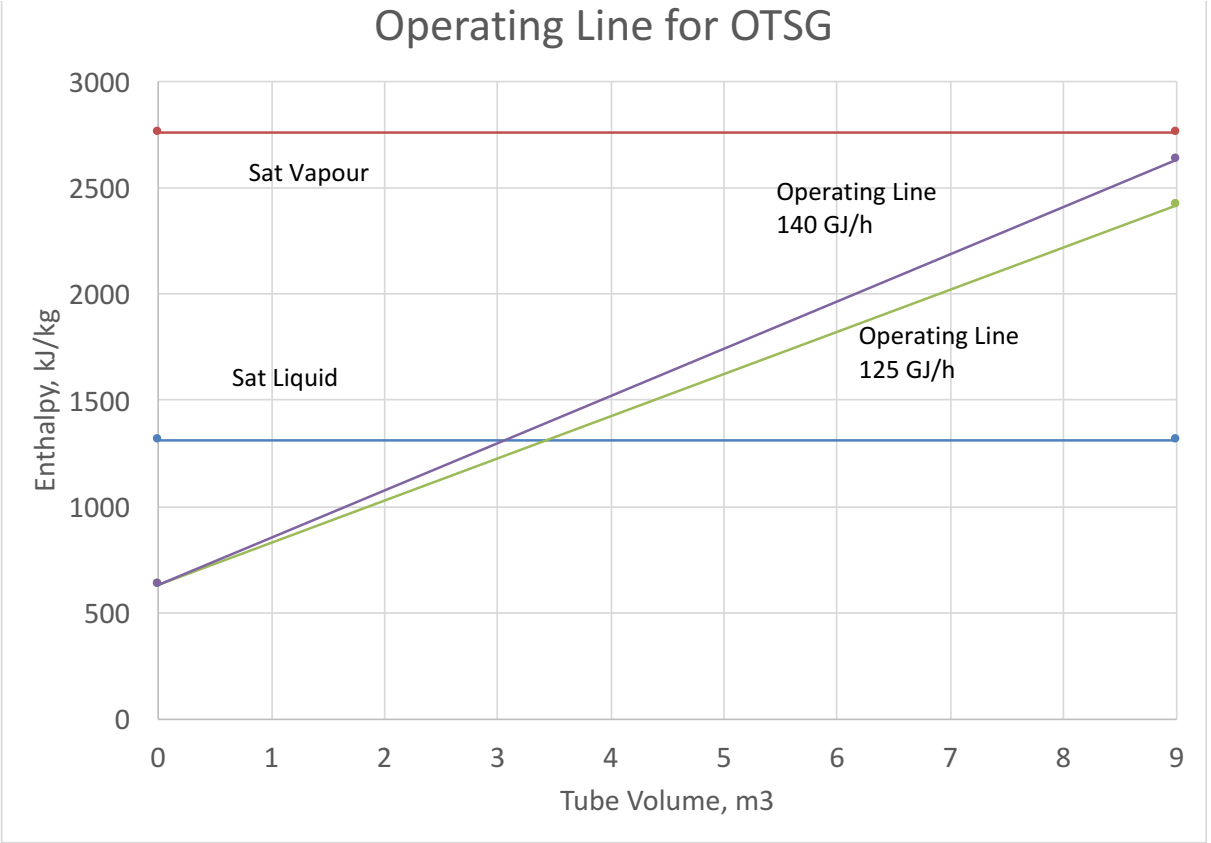
Energy balance. M is mass flow kg/h, H enthalpy kJ/kg, Q heat kJ/h
m x (H_out -H_in) = Q
H_out= H_in + Q/m
H_out= 632 kJ/kg + 125 GJ/h x 1,000,000 kJ/GJ / 70,000 kg/h
Hout = ***2418*** kJ/kg

H = x H_vap + (1 - x) H_liq
H = x (H_vap - H_liq) + H_liq
x = (H - H_liq) / (H_vap - H_liq)
x = (2418 - 1312) / (2760 - 1312)
x = 0.7637 = ***76%***

3) What is the liquid filled volume? How much time is needed for water to travel from the inlet to the boiling location. This is the time needed to reach steady state.

Construct the operating line, saturated liquid and saturated vapour lines

	Inlet	Outlet
Tube vol, m3	0	9
Sat Liq, H	1312	1312
Sat Vap H	2760	2760
Op Line, H	632	2418
Op, high fire	632	2632



By eye, liq volume
3.5 m3

Time to reach boiling location

Inlet density	917	kg/m3
Sat density	724	kg/m3
Average	820	kg/m3

mass flow	70000	kg/h
avg vol flow	85.3	m3/h
Volume	3.5	h
Time	0.041	h
	2.5	min

Using the inlet or saturated density would be close enough.

4) Firing rate is increased from 125 GJ/h to 140 GJ/h. What is new steam quality? Show the new operating line and saturation line. What is the new liquid filled volume? How much water mass was gained or lost by the time the OTSG lines out?

Energy balance. M is mass flow kg/h, H enthalpy kJ/kg, Q heat kJ/h
m x (H_out -H_in) = Q
H_out= H_in + Q/m
H_out= 632 kJ/kg + 140 GJ/h x 1,000,000 kJ/GJ / 70,000 kg/h
Hout = 2632 kJ/kg

H = x H_vap + (1 - x) H_liq
H = x (H_vap - H_liq) + H_liq
x = (H - H_liq) / (H_vap - H_liq)

x = (2632 - 1312) / (2760 - 1312)
x = 0.9117 = ***91%***

Operating line shown on graph above

By eye, liq volume is now
3 m3
Volume water lost
0.5 m3
avg density
820 kg/m3
mass lost
410 kg

5) Assume the water mass is removed uniformly while the OTSG lines out. What is the total outlet mass flow of water + steam during the transient? Does the Venturi DP increase or decrease, and why? Will the estimated steam quality read a false HIGH or a false LOW?

This mass is lost in
0.0410 hour
10000 kg/h extra flow out over 2.5 minutes

This extra mass will cause higher pressure drop in the venturi
Venturi equation is
m_in = K sqrt(density x DP)
or
inferred density = (1 / DP) x (m_in / K)^2

inlet mass flow does not change
measured venturi DP increases
Thus the inferred outlet density decreases. And hence the inferred quality increases.

The venturi will read a false high value during the 2.5 minutes that it takes for the OTSG to line out.