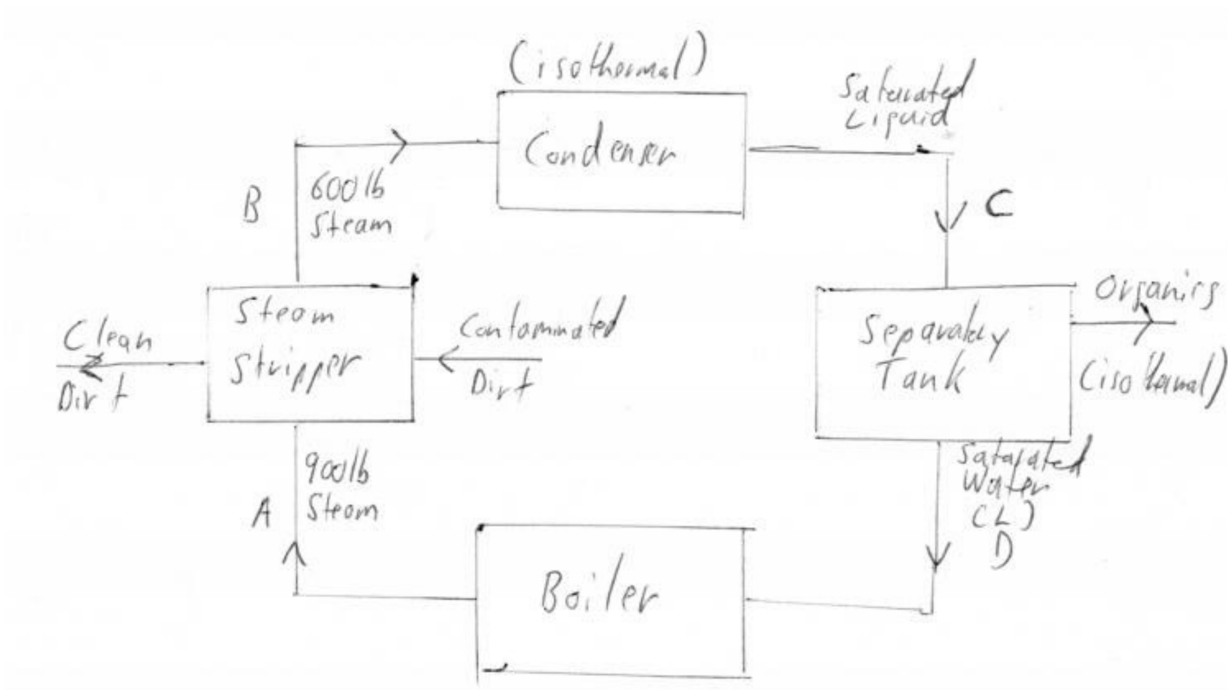
Quiz 1
ChE Thermo 2017
January 12, 2017



Contaminated dirt from a fuel transfer site is to be cleaned. It has been proposed to use a steam stripper to remove the fuel and you need to assess the viability of this proposal. The operation includes a steam stripper fed by 900 lb steam with 600 lb steam leaving the stripper. The 600 lb steam is condensed to saturated water with a small fraction of organics and fed into a separatory tank and then into a boiler. Both the condenser and the separatory tank are isothermal.

The organic contaminant can be modeled as n-octane with the following Antoine constants from the NIST webbook (note T is in °K, P in bar):

Antoine Equation Parameters

$\log_{10}(P) = A - (B / (T + C))$
P = vapor pressure (bar)
T = temperature (K)

View plot Requires a JavaScript / HTML 5 canvas capable browser.

Temperature (K)	A	B	C	Reference	Comment
216.59 - 297.10	5.2012	1936.281	-20.143	Carruth and Kobayashi, 1973	Coefficents calculated by NIST from author's data.
326.08 - 399.72	4.04867	1355.126	-63.633	Williamham, Taylor, et al., 1945	

n-Octane critical point $T_c = 569$°K, $P_c = 24.9$ bar
(Unit conversion 1 atmosphere is 14.7 psi, 1.01 bar, 0.101 MPa, 760 mmHg, 29.9 inHg)

In the chemical industry 900 lb steam refers to 900 psig saturated steam. (psig is gauge pressure such as you would read from a pressure gauge on a process line.)

To answer the following questions most effectively make a table listing P (MPa), T (°C), U kJ/kg, State (SL, SV, SHS, SCL) (SL is saturated liquid, SHS is super heated steam, etc.) for each of the streams A, B, C, D. (You don't need to completely fill this table.)

You can also make a similar table of UL, UV, T, P for the necessary extrapolations from the steam tables. (You don't need to completely fill this table.)

a) What is the temperature for streams A and B. What is ΔU for the steam stream in the stripper?
b) Can this operation remove n-octane from the dirt? (Use the Antoine equation under the assumption that you can extend the temperature range.)
c) What is ΔU for the condenser?
d) Will octane condense into a liquid in the condenser? (Use the Antoine equation under the assumption that you can extend the temperature range. Assume that liquid water and n-octane are completely immiscible.)
e) What is ΔU for the boiler?

Answers
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	P (MPa)	T (°C)	U (kJ/kg)	State
A	6.28	279	2590	SV
B	4.22	254	2600	SV
C	~~4.22~~	254	1090	SL
D	~~4.22~~	254	1090	SL

$$(900\,psi + 14.7\,psi)\frac{0.101\,MPa}{14.7\,psi} = 6.28\,MPa$$

$$(600\,psi + 14.7\,psi)\left(\frac{0.101\,MPa}{14.7\,psi}\right) = 4.22\,MPa$$

U_L kJ/kg	U_V kJ/kg	T °C	MPa
	2590	275	5.95
	2586	280	6.42

$$\Delta T = 5°C\left(\frac{6.28-5.95}{6.42-5.95}\right) = 4\,°C$$

0.70

1080	2600	250	3.98
1100	2600	255	4.32

$$\Delta T = 5°C\left(\frac{4.22-3.98}{4.32-3.98}\right) = 4\,°C$$

0.71

a) $T_A = 279\,°C \quad T_B = 254\,°C$

$\Delta U = -10$ kJ/kg

b) Assume 400 °C can be extended to 552 K

$$P = 10^{4.05 - (1360/(552+(-63.6))} = 18.4 \text{ bar}$$

or 1.84 MPa

1.84 MPa << 5 MPa so the n-octane will not be effectively removed.

c) Condenser is B to C

$$(2600 - 1090)\frac{kJ}{kg} = 1510\, kJ/kg$$

d) The Condenser temperature is 254 °C (527 °K)

P is ~ 5 MPa

From part b) $P_{sat_{octane}} = 10^{4.05 - \left(\frac{1360}{527K - 63.6}\right)}$

$= 13.0$ bar

1.30 MPa

5 MPa >> 1.30 MPa so n-octane would condense

e) Boiler is from D to A

$$\Delta u = 1090 \frac{kJ}{kg} - 2590 \frac{kJ}{kg} = -1500 \frac{kJ}{kg}$$