Upstream LNG Technology
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Lecture – 82
Tutorial on hydrocarbon recovery in natural gas

Welcome, today, in this lecture we shall be doing a few problems on the natural gas recovery.

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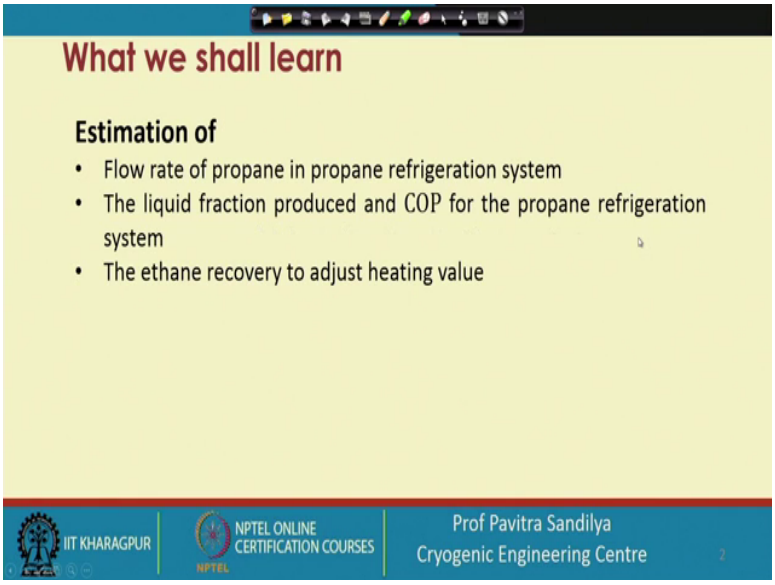

What we shall learn

Estimation of
- Flow rate of propane in propane refrigeration system
- The liquid fraction produced and COP for the propane refrigeration system
- The ethane recovery to adjust heating value

In this what we shall be learning? We shall be learning about, the Estimation of the Flow rate of propane in a propane refrigeration system then, the liquid fraction produced and the, Coefficient Of Performance for the propane refrigeration system and how to estimate the ethane recovery to adjust the heating value.

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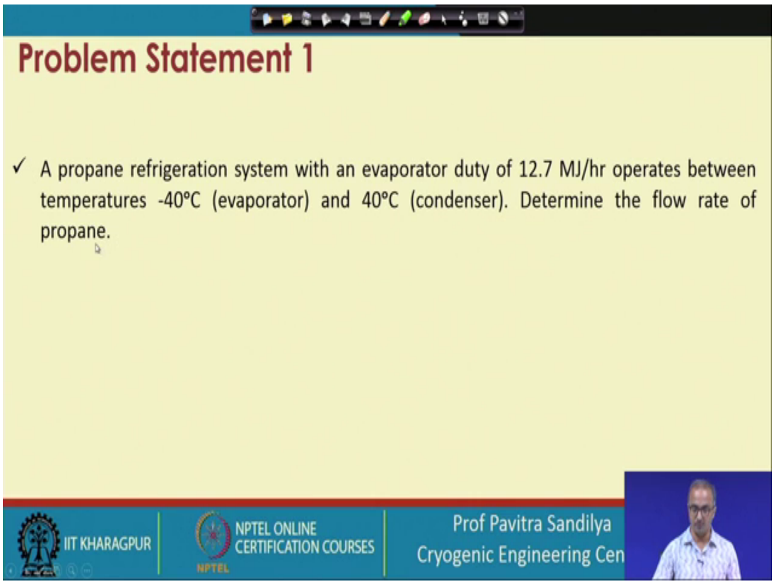

Problem Statement 1

- ✓ A propane refrigeration system with an evaporator duty of 12.7 MJ/hr operates between temperatures -40°C (evaporator) and 40°C (condenser). Determine the flow rate of propane.

So, the first problem is like this, that we have a propane refrigeration system with a evaporator duty given as this value, which is operating between two temperatures that is, minus 40 degree Centigrade which is at the evaporator and 40 degree Centigrade at the condenser and you have to Determine the flow rate of the propane.

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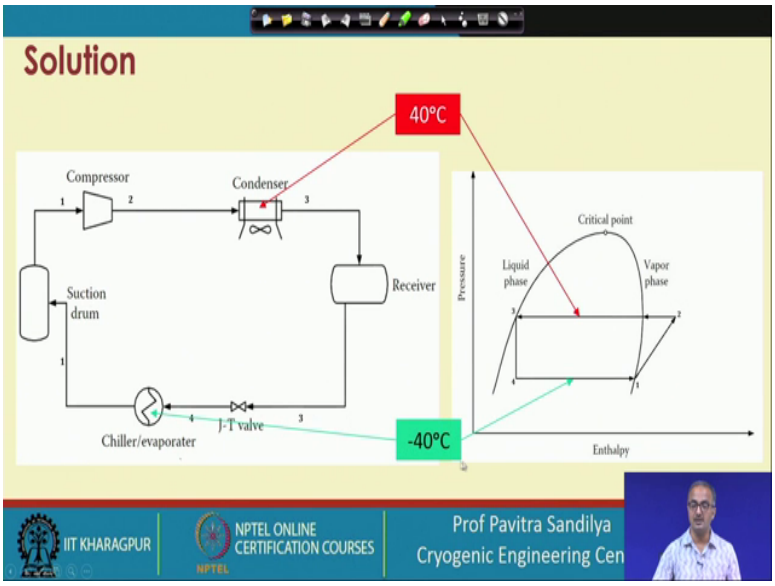

Solution

So, here we again, recapitulate what is the propane, refrigeration system in these this is a Compressor, Condenser receiver and the evaporator, so, J-T valve.

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Now, here what we find that we have also, denoted the various states that the 1, 2, 3, and 4. So, these are, four states through which the propane is undergoing the cycle and along with that is the, pressure Enthalpy diagram on which, we are showing those change in the states starting from the 1 to 2 that is, from the Compressor. So, is a Compressor then the Condenser then the J-T effect rather, isenthalpic expansion and then we have ultimately rather chiller.

So, this is how these things are going on, and we are not going to details of this because these have been, told to you in a separate lecture. We are just demarcating the, particular, data which have been given to us. So, here in the condenser the temperature is about 40 degree Centigrade and in the chiller it is that minus 40 degree Centigrade.

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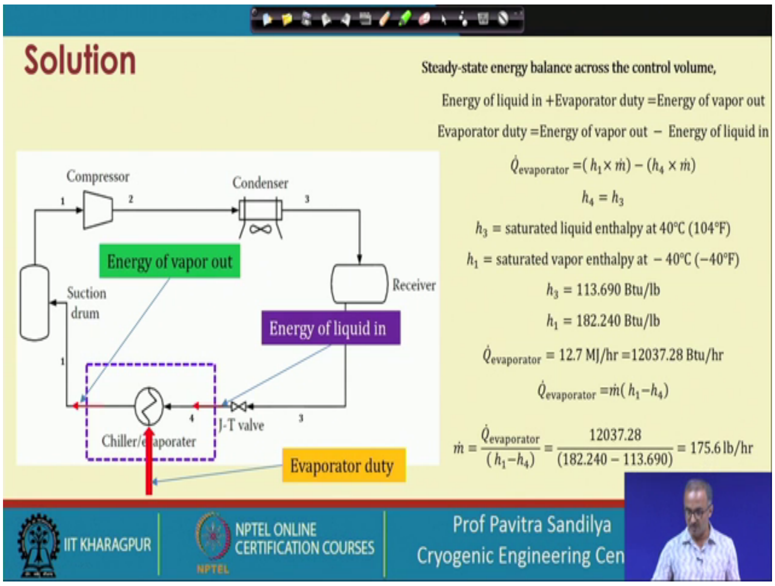

Solution

Steady-state energy balance across the control volume,

Energy of liquid in + Evaporator duty = Energy of vapor out

Evaporator duty = Energy of vapor out − Energy of liquid in

$$\dot{Q}_{evaporator} = (h_1 \times \dot{m}) - (h_4 \times \dot{m})$$

$$h_4 = h_3$$

h_3 = saturated liquid enthalpy at 40°C (104°F)

h_1 = saturated vapor enthalpy at −40°C (−40°F)

$$h_3 = 113.690 \text{ Btu/lb}$$

$$h_1 = 182.240 \text{ Btu/lb}$$

$$\dot{Q}_{evaporator} = 12.7 \text{ MJ/hr} = 12037.28 \text{ Btu/hr}$$

$$\dot{Q}_{evaporator} = \dot{m}(h_1 - h_4)$$

$$\dot{m} = \frac{\dot{Q}_{evaporator}}{(h_1 - h_4)} = \frac{12037.28}{(182.240 - 113.690)} = 175.6 \text{ lb/hr}$$

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So, these are the two temperatures given to us. And now, what we are doing that, we shall be writing a steady state energy balance across the Chiller to know the flow rate. So, at steady state we have the energy that is going in and energy it is going out and energy is also coming in, from the space which is to be refrigerated ok. So, from there we are getting this thing and this is nothing but the evaporator duty.

So, these are the energy effects and here we are neglecting any other energy heat inlet from the ambient in to the system or heat outlet from the system to the ambient. So, under these assumptions for a steady state energy balance we know that, energy that is going into the energy that is also coming into the evaporator duty is equal to the energy of the vapor out.

So, here we are writing this, Q evaporator is equal to like this that h 1 has a h 1 here into m dot minus h 4 into m dot ok.

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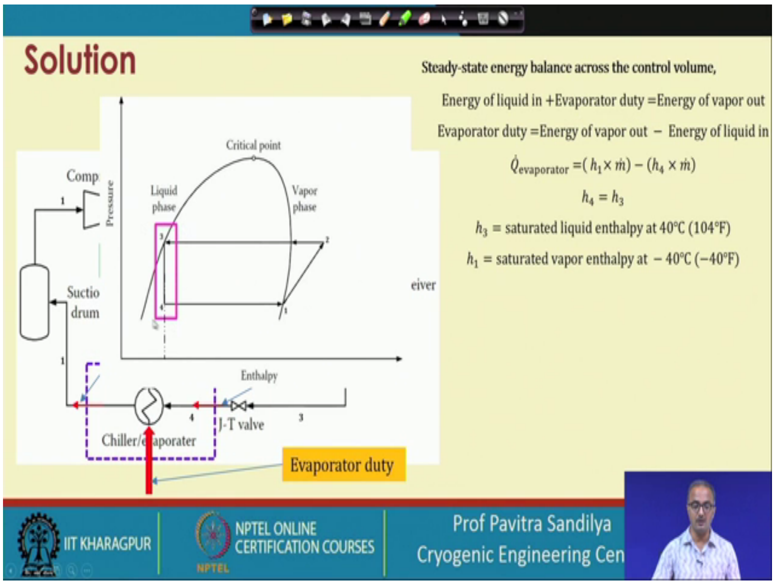

Solution

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Energy of liquid in +Evaporator duty =Energy of vapor out

Evaporator duty =Energy of vapor out − Energy of liquid in

$$\dot{Q}_{evaporator} = (h_1 \times \dot{m}) - (h_4 \times \dot{m})$$

$$h_4 = h_3$$

h_3 = saturated liquid enthalpy at 40°C (104°F)

h_1 = saturated vapor enthalpy at − 40°C (−40°F)

Now, this h 1 and is h 3 is what that h 1 is equal to h 3 because we know this is an isenthalpic expansion. So, that is h 3 is equal to h 4. So and h 3 is the saturated liquid enthalpy at 40 degree Centigrade. From here we find that at this whatever enthalpy is there this is the enthalpy at 40 degree Centigrade for the saturated liquid for the same enthalpy will be there also for this h 4.

And h 1 is the saturated vapor enthalpy at minus 40 degree Centigrade. So, this is the enthalpy which is the enthalpy for the, inlet gas stream and, we are converting this degree Centigrade into degree Fahrenheit why because, the thermodynamic charts which are available to us they are given in the FPS system. ,

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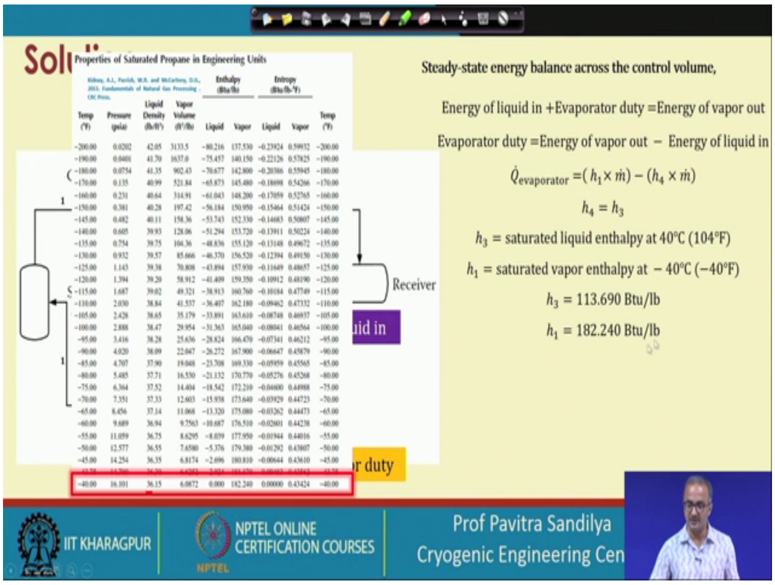

Properties of Saturated Propane in Engineering Units

Temp (°F)	Pressure (psia)	Liquid Density (lb/ft³)	Vapor Volume (ft³/lb)	Enthalpy (Btu/lb) Liquid	Enthalpy (Btu/lb) Vapor	Entropy (Btu/lb-°F) Liquid	Entropy (Btu/lb-°F) Vapor	Temp (°F)
-200.00	0.0202	42.05	3133.5	-80.216	137.530	-0.23924	0.59932	-200.00
-190.00	0.0401	41.70	1637.0	-75.457	140.150	-0.22126	0.57825	-190.00
-180.00	0.0754	41.35	902.43	-70.677	142.800	-0.20386	0.55945	-180.00
-170.00	0.135	40.99	521.84	-65.873	145.480	-0.18698	0.54266	-170.00
-160.00	0.231	40.64	314.91	-61.043	148.200	-0.17059	0.52765	-160.00
-150.00	0.381	40.28	197.42	-56.184	150.950	-0.15464	0.51424	-150.00
-145.00	0.482	40.11	158.36	-53.743	152.330	-0.14683	0.50807	-145.00
-140.00	0.605	39.93	128.06	-51.294	153.720	-0.13911	0.50224	-140.00
-135.00	0.754	39.75	104.36	-48.836	155.120	-0.13148	0.49672	-135.00
-130.00	0.932	39.57	85.666	-46.370	156.520	-0.12394	0.49150	-130.00
-125.00	1.143	39.38	70.808	-43.894	157.930	-0.11649	0.48657	-125.00
-120.00	1.394	39.20	58.912	-41.409	159.350	-0.10912	0.48190	-120.00
-115.00	1.687	39.02	49.321	-38.913	160.760	-0.10184	0.47749	-115.00
-110.00	2.030	38.84	41.537	-36.407	162.180	-0.09462	0.47332	-110.00
-105.00	2.428	38.65	35.179	-33.891	163.610	-0.08748	0.46937	-105.00
-100.00	2.888	38.47	29.954	-31.363	165.040	-0.08041	0.46564	-100.00
-95.00	3.416	38.28	25.636	-28.824	166.470	-0.07341	0.46212	-95.00
-90.00	4.020	38.09	22.047	-26.272	167.900	-0.06647	0.45879	-90.00
-85.00	4.707	37.90	19.048	-23.708	169.330	-0.05959	0.45565	-85.00
-80.00	5.485	37.71	16.530	-21.132	170.770	-0.05276	0.45268	-80.00
-75.00	6.364	37.52	14.404	-18.542	172.210	-0.04600	0.44988	-75.00
-70.00	7.351	37.33	12.603	-15.938	173.640	-0.03929	0.44723	-70.00
-65.00	8.456	37.14	11.068	-13.320	175.080	-0.03262	0.44473	-65.00
-60.00	9.689	36.94	9.7563	-10.687	176.510	-0.02601	0.44238	-60.00
-55.00	11.059	36.75	8.6295	-8.039	177.950	-0.01944	0.44016	-55.00
-50.00	12.577	36.55	7.6580	-5.376	179.380	-0.01292	0.43807	-50.00
-45.00	14.254	36.35	6.8174	-2.696	180.810	-0.00644	0.43610	-45.00
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
-40.00	16.101	36.15	6.0872	0.000	182.240	0.00000	0.43424	-40.00

Steady-state energy balance across the control volume,

Energy of liquid in + Evaporator duty = Energy of vapor out

Evaporator duty = Energy of vapor out − Energy of liquid in

$$\dot{Q}_{evaporator} = (h_1 \times \dot{m}) - (h_4 \times \dot{m})$$

$$h_4 = h_3$$

h_3 = saturated liquid enthalpy at 40°C (104°F)

h_1 = saturated vapor enthalpy at − 40°C (−40°F)

$$h_3 = 113.690 \text{ Btu/lb}$$

$$h_1 = 182.240 \text{ Btu/lb}$$

So, this is the our study, with the continuum for study and here we have in from these properties of this saturated propane in, engineering units. So, here we have this from this particular reference we have taken this data and for this 140 degree Fahrenheit we find these are the data for the saturated vapor.

So, from here we find out the enthalpy which that is for the vapor that is about 2; this 225 is the vapor enthalpy, for 140 degree Fahrenheit, sorry these are liquid enthalpy we are taking this 113.690 as the liquid enthalpy, from this table and we are taking at minus 40 degree, Fahrenheit we are taking the vapor enthalpy to be 128.24. So, here were reading these values and were putting these values over here.

Now, what we do after doing this, we are simply plugging in the values, in this particular equation and we are getting the flow rate has the Evaporated duty divided by the difference between these two enthalpies and after plugging the values we find this is the value of the flow rate. So, this is the flow rate of the propane through the system ok, and we see that how we are using the energy balance equation and the consumer constellation that there is a isenthalpic expansion through the J-T valve we are able to solve for the mass flow rate of the propane.

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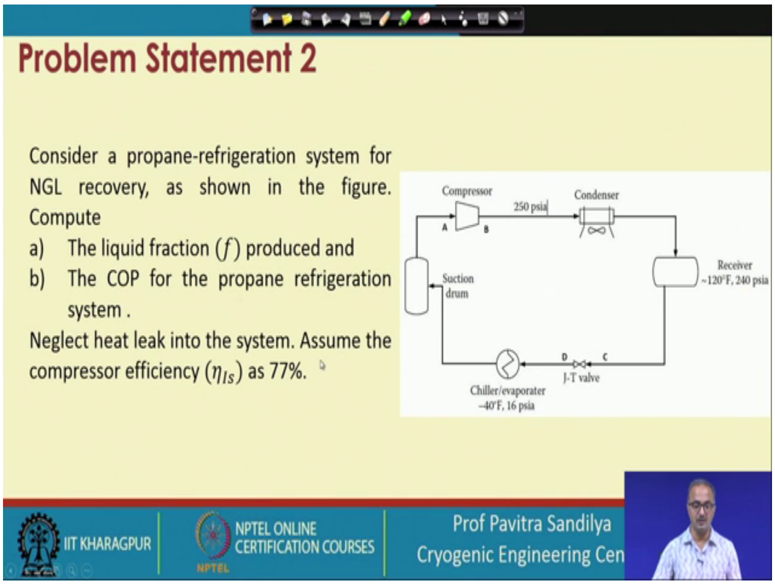

Problem Statement 2

Consider a propane-refrigeration system for NGL recovery, as shown in the figure. Compute

a) The liquid fraction (f) produced and

b) The COP for the propane refrigeration system .

Neglect heat leak into the system. Assume the compressor efficiency (η_{Is}) as 77%.

Now, we come to and the same system now, here what we are doing that we have to find out The liquid fraction produced and The COP of the refrigeration system. And here we have been given that we assume that compressor efficiency is about 77 percent and heat a leak into the system is neglected.

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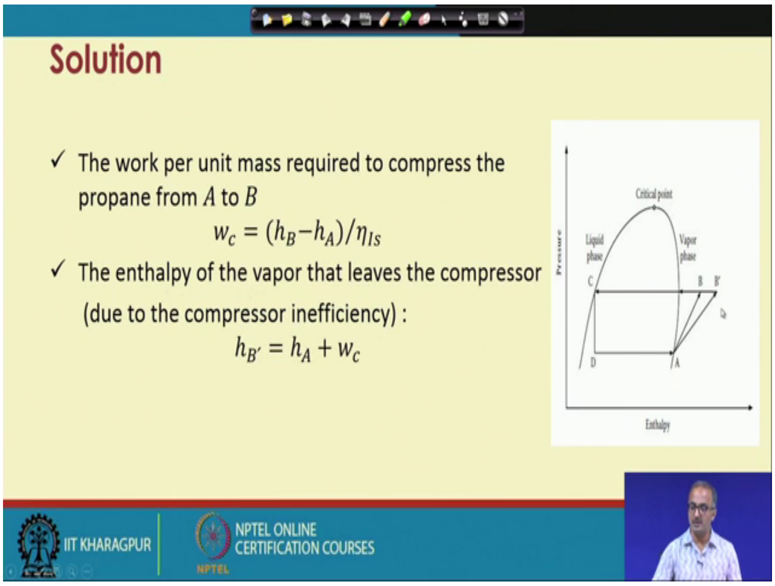

Solution

- ✓ The work per unit mass required to compress the propane from A to B

$$w_c = (h_B - h_A)/\eta_{Is}$$

- ✓ The enthalpy of the vapor that leaves the compressor (due to the compressor inefficiency) :

$$h_{B'} = h_A + w_c$$

So, again we write that, the work done is this we have derived earlier also. So, we find that work done is h B minus h A; that means, this is the compressor ok. So, the work is done only at the compressor. So, we are writing that h B minus h A divided by eta is because actual work will be from A to B prime. So, this A to B and this is the ideal work. So, this A to B prime has been taken as in terms of a A to B and divided by this in efficiency of the isentropic this compression.

And these the enthalpy of the vapor leaving the, compressor is h B prime h B prime here, this h B prime this h B prime equal to h A plus this W c.

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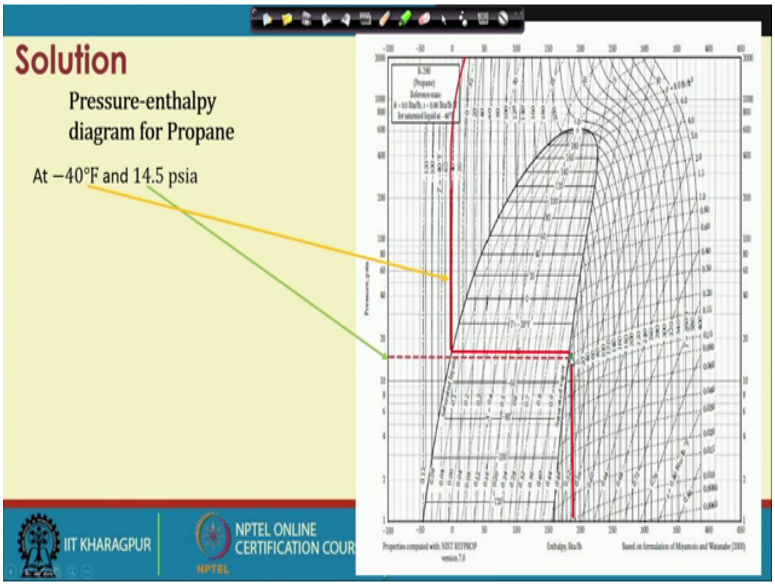

Solution

Pressure-enthalpy diagram for Propane

At −40°F and 14.5 psia

Now, because we need all the values of the enthalpies so, we need to refer to the Pressure-enthalpy, data for Propane and here we have the diagram for the Pressure-enthalpy of Propane. Here we find that we have these we can see that these are the constant temperature lines these, solid lines are the constant temperature lines and here also you find the constant density line over here ok. And this particular curve is for the saturate liquid and this particular curve is for the saturated vapor.

So, with this, what we do that, for minus 40 degree Fahrenheit and 14.5 psia. We find out the this is the one this particular line is for the minus 40 degree Fahrenheit and from here we can note down that wherever it is, this, intersecting this line from this we find out the value of the.

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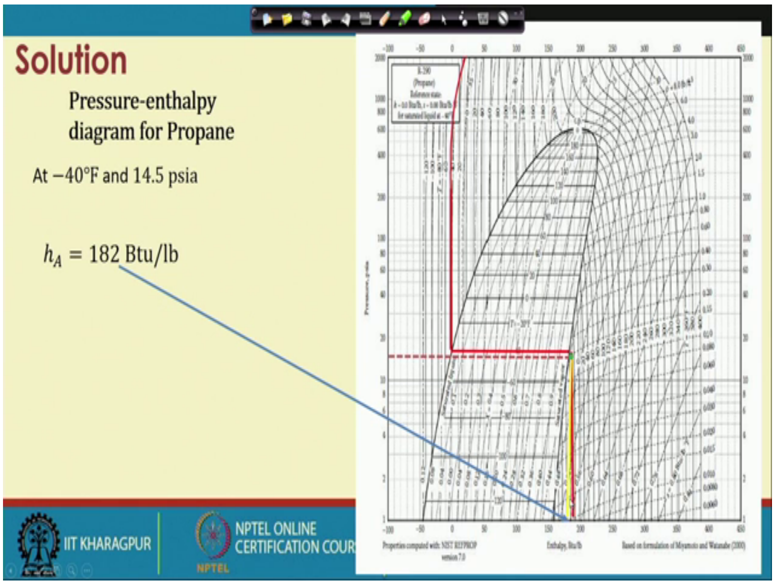

Solution

Pressure-enthalpy diagram for Propane

At −40°F and 14.5 psia

$h_A = 182$ Btu/lb

This we, find this value, and here we have get the value of the h A as this one we are reading from the enthalpy we are reading from the x axis. So, this is the, value of the h A.

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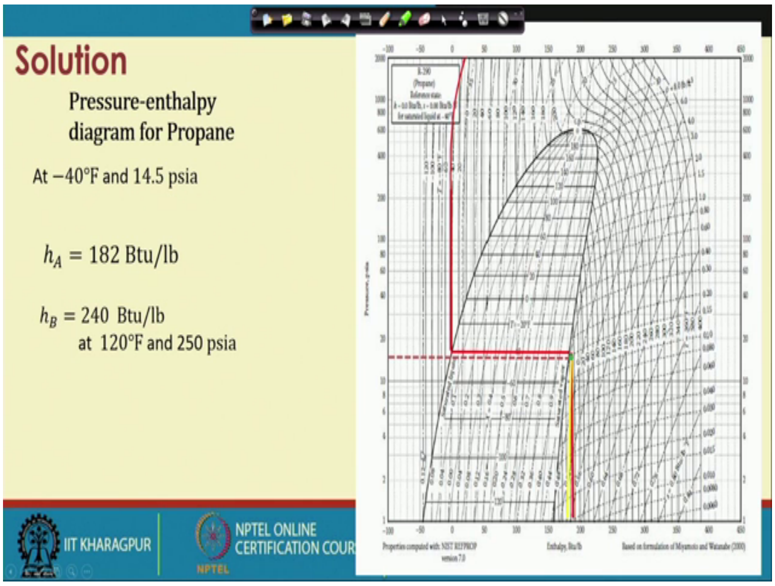

Solution

Pressure-enthalpy diagram for Propane

At −40°F and 14.5 psia

$h_A = 182$ Btu/lb

$h_B = 240$ Btu/lb at 120°F and 250 psia

And then we have the h B value this is again coming from the 120 degree Fahrenheit and 250 psia. So, here this is the line for the 120 degree Fahrenheit and if here we have the, 250 psia will be somewhere over here. So, from somewhere here we are reading the value again of the h, from the, x axis and.

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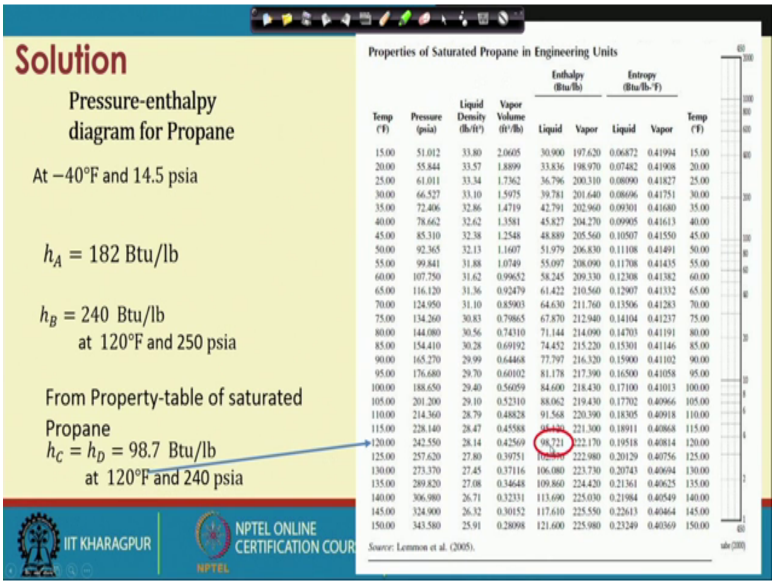

Solution

Pressure-enthalpy diagram for Propane

At −40°F and 14.5 psia

h_A = 182 Btu/lb

h_B = 240 Btu/lb
at 120°F and 250 psia

From Property-table of saturated Propane
$h_C = h_D$ = 98.7 Btu/lb
at 120°F and 240 psia

Properties of Saturated Propane in Engineering Units

Temp (°F)	Pressure (psia)	Liquid Density (lb/ft³)	Vapor Volume (ft³/lb)	Enthalpy (Btu/lb) Liquid	Enthalpy (Btu/lb) Vapor	Entropy (Btu/lb-°F) Liquid	Entropy (Btu/lb-°F) Vapor	Temp (°F)
15.00	51.012	33.80	2.0605	30.900	197.620	0.06872	0.41994	15.00
20.00	55.844	33.57	1.8899	33.836	198.970	0.07482	0.41908	20.00
25.00	61.011	33.34	1.7362	36.796	200.310	0.08090	0.41827	25.00
30.00	66.527	33.10	1.5975	39.781	201.640	0.08696	0.41751	30.00
35.00	72.406	32.86	1.4719	42.791	202.960	0.09301	0.41680	35.00
40.00	78.662	32.62	1.3581	45.827	204.270	0.09905	0.41613	40.00
45.00	85.310	32.38	1.2548	48.889	205.560	0.10507	0.41550	45.00
50.00	92.365	32.13	1.1607	51.979	206.830	0.11108	0.41491	50.00
55.00	99.841	31.88	1.0749	55.097	208.090	0.11708	0.41435	55.00
60.00	107.750	31.62	0.99652	58.245	209.330	0.12308	0.41382	60.00
65.00	116.120	31.36	0.92479	61.422	210.560	0.12907	0.41332	65.00
70.00	124.950	31.10	0.85903	64.630	211.760	0.13506	0.41283	70.00
75.00	134.260	30.83	0.79865	67.870	212.940	0.14104	0.41237	75.00
80.00	144.080	30.56	0.74310	71.144	214.090	0.14703	0.41191	80.00
85.00	154.410	30.28	0.69192	74.452	215.220	0.15301	0.41146	85.00
90.00	165.270	29.99	0.64468	77.797	216.320	0.15900	0.41102	90.00
95.00	176.680	29.70	0.60102	81.178	217.390	0.16500	0.41058	95.00
100.00	188.650	29.40	0.56059	84.600	218.430	0.17100	0.41013	100.00
105.00	201.200	29.10	0.52310	88.062	219.430	0.17702	0.40966	105.00
110.00	214.360	28.79	0.48828	91.568	220.390	0.18305	0.40918	110.00
115.00	228.140	28.47	0.45588	[illegible]	221.300	0.18911	0.40868	115.00
120.00	242.550	28.14	0.42569	98.721	222.170	0.19518	0.40814	120.00
125.00	257.620	27.80	0.39751	[illegible]	222.980	0.20129	0.40756	125.00
130.00	273.370	27.45	0.37116	106.080	223.730	0.20743	0.40694	130.00
135.00	289.820	27.08	0.34648	109.860	224.420	0.21361	0.40625	135.00
140.00	306.980	26.71	0.32331	113.690	225.030	0.21984	0.40549	140.00
145.00	324.900	26.32	0.30152	117.610	225.550	0.22613	0.40464	145.00
150.00	343.580	25.91	0.28098	121.600	225.980	0.23249	0.40369	150.00

Source: Lemmon et al. (2005).

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And this is the property of table for the saturated propane and from here we find the values of at this one 20 Fahrenheit and 240 psia we find this is the value of the enthalpy and at hC and hD.

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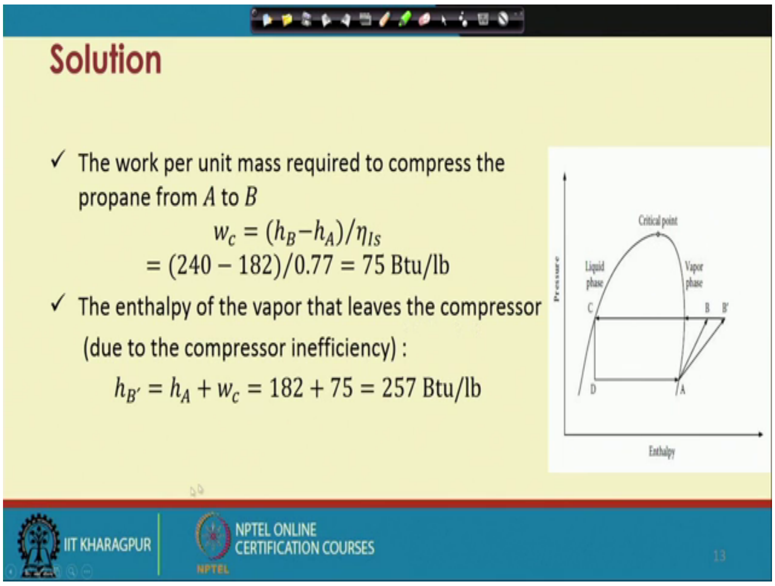

Solution

- ✓ The work per unit mass required to compress the propane from *A* to *B*
$$w_c = (h_B - h_A)/\eta_{Is}$$
$$= (240 - 182)/0.77 = 75 \text{ Btu/lb}$$
- ✓ The enthalpy of the vapor that leaves the compressor (due to the compressor inefficiency) :
$$h_{B'} = h_A + w_c = 182 + 75 = 257 \text{ Btu/lb}$$

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And, now we simply plug in the values to find out the work done per unit mass of the gas compressed and we also find out the actual enthalpy of a vapor that is leave in the Compressor from this particular formula ok.

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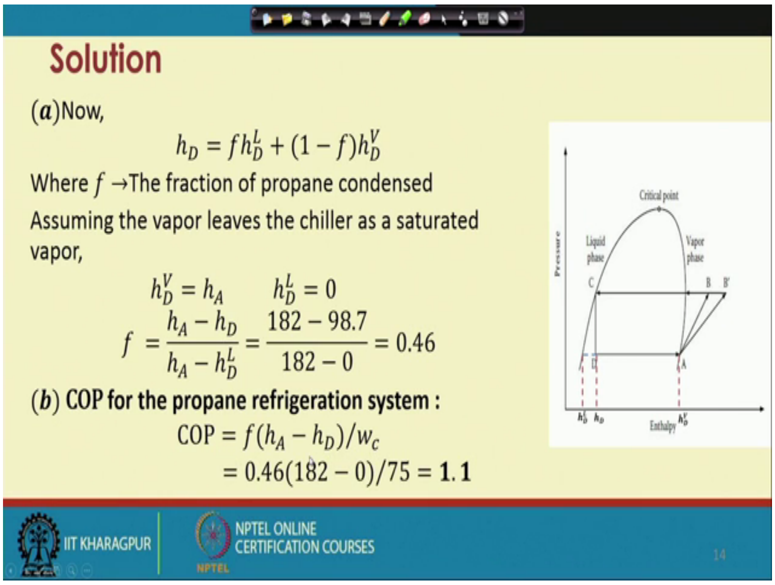

Solution

(*a*)Now,

$$h_D = f h_D^L + (1-f) h_D^V$$

Where f →The fraction of propane condensed

Assuming the vapor leaves the chiller as a saturated vapor,

$$h_D^V = h_A \qquad h_D^L = 0$$

$$f = \frac{h_A - h_D}{h_A - h_D^L} = \frac{182 - 98.7}{182 - 0} = 0.46$$

(*b*) COP for the propane refrigeration system :

$$\text{COP} = f(h_A - h_D)/w_c$$

$$= 0.46(182 - 0)/75 = \mathbf{1.1}$$

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So, this is how we can solve for the work done and then, what we do that we needs to know the h (( )); and h D, we know that this will be somewhere here and to know this h D what we do we take the help of the enthalpies of the saturated liquid and the saturated vapor and for this we need the f that is the, amount of the fraction of the liquid present in the mixture.

So, we write this particular formula to get the value of the enthalpy at this point, and we find that we take that h D V to be same as the h A. So, we are take because, the h is taken to be the saturated vapor. So, h A same as the h D V and we are taking that h D L to be 0, and we get from this formula this particular value this that is the about 46 percent of the gas is being liquefied. And COP of the gas is, this from the formula we derived earlier in our lecture through we plug in the values and we get the COP to be about 1.1.

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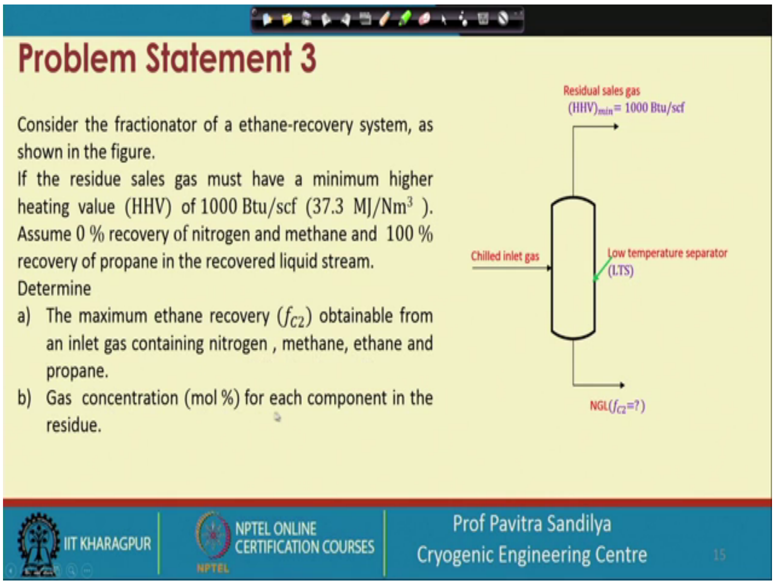

Problem Statement 3

Consider the fractionator of a ethane-recovery system, as shown in the figure.

If the residue sales gas must have a minimum higher heating value (HHV) of 1000 Btu/scf (37.3 MJ/Nm^3). Assume 0 % recovery of nitrogen and methane and 100 % recovery of propane in the recovered liquid stream.

Determine

a) The maximum ethane recovery (f_{C2}) obtainable from an inlet gas containing nitrogen , methane, ethane and propane.

b) Gas concentration (mol %) for each component in the residue.

Now, we come to another problem; in this problem we are having this ethane-recovery in the fractionator. So, here we are considering that where we have already the chilled in gas and as we have, studied earlier that the inlet feed gas is comes through a propane chiller and other chilled by the vapor or residual gas. So, from that we are getting this particular, chilled inlet gas and that is going to the fractionator and here we are this, it is top we are getting the gas and from the bottom we are getting the NGL.

So, what we have been ask that if the residue gas sales gas must have a minimum higher heating value of this 1000 Btu per scf. So, here this particular residual gas this is the minimum amount of the heating value of the, Residual gas and we assumed that 0 percent recovery of nitrogen and methane and 100 percent recovery of propane in the recovered liquid stream; that means, none 0 percent recovery means none of the methane and nitrogen is going out with the NGL; that means, all of them are going with Residual gas and 100 percent recovery of propane means, the whatever propane is there in the inlet gas all of heat is going into the NGL and none is going into the vapor stream upward. That means, what that, accept ethane all the gases are either remaining in the liquid phase or in the vapor phase only ethane, is going with both the, vapor phase and the liquid phase.

So, we have to determine the maximum ethane recovery obtainable from the inlet gas comprising nitrogen methane ethane and propane and the gas concentration mol percent for each component in the residue.

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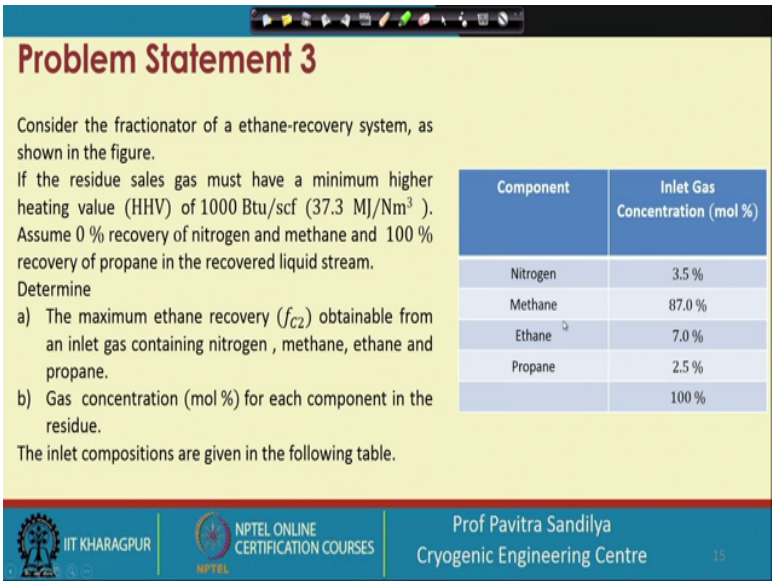

Problem Statement 3

Consider the fractionator of a ethane-recovery system, as shown in the figure.

If the residue sales gas must have a minimum higher heating value (HHV) of 1000 Btu/scf (37.3 MJ/Nm^3). Assume 0 % recovery of nitrogen and methane and 100 % recovery of propane in the recovered liquid stream.

Determine

a) The maximum ethane recovery (f_{C2}) obtainable from an inlet gas containing nitrogen , methane, ethane and propane.

b) Gas concentration (mol %) for each component in the residue.

The inlet compositions are given in the following table.

Component	Inlet Gas Concentration (mol %)
Nitrogen	3.5 %
Methane	87.0 %
Ethane	7.0 %
Propane	2.5 %
	100 %

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So, what we do that this is the inlet gas composition given to us that is, 3.5 percent a Nitrogen, 87 percent Methane, 7 percent Ethane and 2.5 percent Propane and this how to change that whether it is right or not what we do we just add them up and find it is coming to 100 percent.

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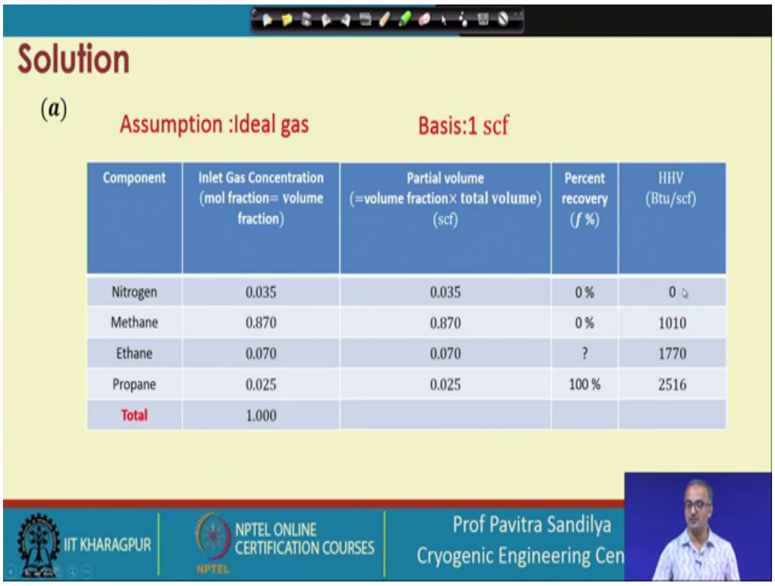

Solution

(*a*)

Assumption :Ideal gas

Basis:1 scf

Component	Inlet Gas Concentration (mol fraction= volume fraction)	Partial volume (=volume fraction× total volume) (scf)	Percent recovery (f %)	HHV (Btu/scf)
Nitrogen	0.035	0.035	0 %	0
Methane	0.870	0.870	0 %	1010
Ethane	0.070	0.070	?	1770
Propane	0.025	0.025	100 %	2516
Total	1.000			

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Now, what we do that we are assuming to be Ideal gas after assuming Ideal gas, we find and we are taking a basis of one, scf that is the standard cubic feet and with this assumption if you find that mol fraction is equal to volume fraction in case of ideal gas. So, if we multiply the this volume fraction with this one scf you will get the partial volume of each of the components and that is what we have found here.

Now, what we do that these are the percent recovery as these given in the problem that nothing is going in the liquid. So, Nitrogen Methane. So, we finding that recovery of where these two components are 0 and the whole of the propane is going to liquid into 100 percent recovery for the Propane and we do not know how much is the Ethane recovery.

And because we have to meet the, heating value requirement at the top gas so, we also need to know the, component heating values, for the mixture because these will constitute the, contribute to the total heating value of the top gas. So, here we find that nitrogen is supposed to have no heating value and only the a hydrocarbons are we are having the heating value.

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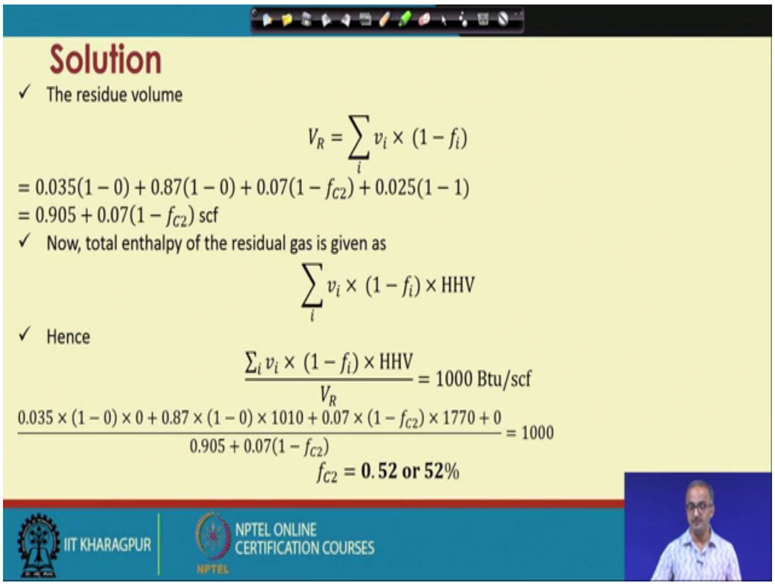

Solution

- ✓ The residue volume

$$V_R = \sum_i v_i \times (1 - f_i)$$

$$= 0.035(1 - 0) + 0.87(1 - 0) + 0.07(1 - f_{C2}) + 0.025(1 - 1)$$

$$= 0.905 + 0.07(1 - f_{C2}) \text{ scf}$$

- ✓ Now, total enthalpy of the residual gas is given as

$$\sum_i v_i \times (1 - f_i) \times \text{HHV}$$

- ✓ Hence

$$\frac{\sum_i v_i \times (1 - f_i) \times \text{HHV}}{V_R} = 1000 \text{ Btu/scf}$$

$$\frac{0.035 \times (1 - 0) \times 0 + 0.87 \times (1 - 0) \times 1010 + 0.07 \times (1 - f_{C2}) \times 1770 + 0}{0.905 + 0.07(1 - f_{C2})} = 1000$$

$$f_{C2} = \mathbf{0.52 \text{ or } 52\%}$$

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Now, the residual volume that is the volume which is going with the gas is obtained like this, we are summing up with the partial volume and 1 minus recovery that is this is the fraction which is going with the top gas. So, we plug in the values of all these, things and; we get this particular Residual gas volume in terms of the unknown, for the recovery of the Ethane.

And now we find the total enthalpy of the residual gas from this particular formula again this in average, volume fraction based formula. So, we are doing that volume of the, each of the gases into 1 minus f i into HHV of each of the components and this will be total, divided by the total amount total volume of the gas will be the this whatever is the desired minimum HHV of the Residual gas.

So, we will be plugging the values of all these particular variables we find this is the fraction of the Ethane that is going, out in the, system that is 52 percent of the Ethane is going with the liquid and rest 48 percent is going with the vapor.

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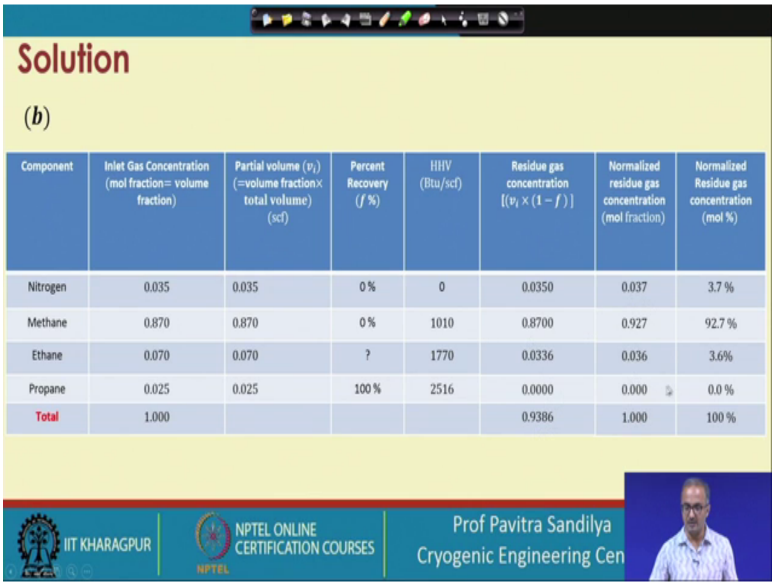

Solution

(*b*)

Component	Inlet Gas Concentration (mol fraction= volume fraction)	Partial volume (v_i) (=volume fraction× total volume) (scf)	Percent Recovery (f %)	HHV (Btu/scf)	Residue gas concentration [$(v_i \times (1-f)$]	Normalized residue gas concentration (mol fraction)	Normalized Residue gas concentration (mol %)
Nitrogen	0.035	0.035	0 %	0	0.0350	0.037	3.7 %
Methane	0.870	0.870	0 %	1010	0.8700	0.927	92.7 %
Ethane	0.070	0.070	?	1770	0.0336	0.036	3.6%
Propane	0.025	0.025	100 %	2516	0.0000	0.000	0.0 %
Total	1.000				0.9386	1.000	100 %

Now, the next part of the question was to find out the composition of the residual gas. So, in this case what we do that now, we again recalculate the residual gas concentration, from this particular formula that v i into 1 minus f i. So, we are getting this, getting these values and this is coming out to about total is about 0.9386.

And now that is this is the total one and to find out the composition what we simply do. We just divide each of these values, with this value and then, what we do? And we do this we are getting this these values and we find that ultimately this will, add up to 1 and in percentage what we do that we just simply multiply each of these with 100 and we get in percentage term that we find that in the Residual gas where the initially it was, 3.5 percent it has increased to the 3.7 percent; Methane was 87 percent it has now gone up to 92.7 percent, the Ethane was 7 percent it has now, gone down the 23.6 percent because rest of it has gone with the liquid down, and this down 2.5 percent it is nothing; that means, no, propane has gone with the Residual gas from the top. So, this is how we are able to find out the, composition of the residual gas.

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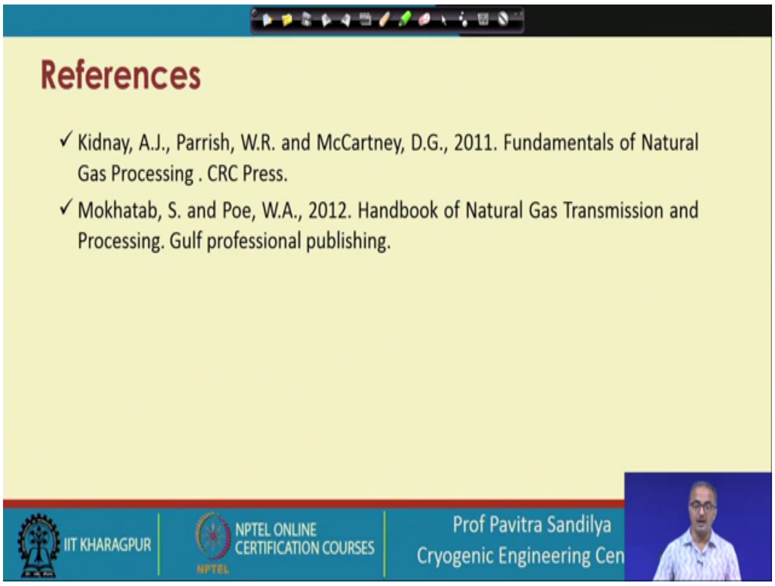

References

- ✓ Kidnay, A.J., Parrish, W.R. and McCartney, D.G., 2011. Fundamentals of Natural Gas Processing . CRC Press.
- ✓ Mokhatab, S. and Poe, W.A., 2012. Handbook of Natural Gas Transmission and Processing. Gulf professional publishing.

And these are the various references we may refer to for detail of these processes.

Thank you.