THERMAL DISTILLATION OF CRUDE OIL

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Abstract - Crude oil extracted from the earth contains many elements that are to be separated for it to be a useful fuel of chemical or raw material. Crude oil refineries are put in place to convert or refine unprocessed crude oil into more useful products using both physical separation and chemical conversion processes. Albeit, different refining units are subsets of the physical separation category. The atmospheric and vacuum distillation unit seems to be more prominent.

Crude oil distillation unit (CDU) is significant in a refinery, and retrofitting a crude oil distillation unit is more common than building a new one. To build a rigorous model for the crude oil distillation unit based on the conventional two-furnace and three-column process flow in a refinery that addresses both the distillation columns and the heat exchanger network (HEN) simultaneously.

The effect of the differences of crude oil properties on the product yield, pump rounds for heat removals, the design of heat exchanger networks, and CO2 emissions in crude distillation units are focused. Furthermore, energy use improvement for crude oil distillation units with consideration of light and heavy crude oil is proposed. Conventionally, the crude atmospheric residue cannot be further heated in an atmospheric condition due to: coke formation, pipes plugging, thermal cracking, and straining of the furnace.

KEYWORDS: Crude oil, CDU, HEN, retrofitting, refinery

1.INTRODUCTION

What Is an HVAC System?

First and foremost, HVAC stands for heating, ventilation, and air conditioning. This system provides heating and cooling to residential and commercial buildings. You can find HVAC systems anywhere from single-family homes to submarines where they provide the means for environmental comfort. Becoming more and more popular in new construction, these systems use fresh air from outdoors to provide high indoor air quality. The V in HVAC, or ventilation, is the process of replacing or exchanging air within a space. This provides a better quality of air indoors and involves the removal of moisture, smoke, odours, heat, dust, airborne bacteria, carbon dioxide, and other gases as well as temperature control and oxygen replenishment.

How Does an HVAC System Work?

The three main functions of an HVAC system are interrelated, especially when providing acceptable indoor air quality and thermal comfort. You're heating and air conditioning system is often one of the most complicated and extensive systems in your home, but when it stops working, you'll know soon enough! There are nine parts to your HVAC system that you should be familiar with the air return, filter, exhaust outlets, ducts, electrical elements, outdoor unit, compressor, coils and blower.

2.REFINING OF CRUDE OIL

Refining of crude oils essentially consists of primary separation processes and secondary conversion processes. The petroleum refining process is the separation of the different hydrocarbons present in the crude oil into useful fractions and the conversion of some of the hydrocarbons into products having higher quality performance. Atmospheric and vacuum distillation of crude oils are the main primary separation processes producing various straight run products, e.g., gasoline to lube oils/vacuum gas oils. Distillation of crude oil is typically performed first under atmospheric pressure and then under a vacuum. Low boiling fractions usually vaporize below 400°C at atmospheric pressure without cracking the hydrocarbon compounds. Therefore, all the low boiling fractions of crude oil are separated by atmospheric distillation. A crude distillation unit (CDU) consists of pre-flash distillation column. The petroleum products obtained from the distillation process are light, medium, and heavy naphtha, gasoline, kerosene, diesel, and oil residue.

Crude oil obtained from the desalter at temperature of 250 °C–260 °C is further heated by a tube-still heater to a temperature of 350 °C–360 °C. The hot crude oil is then passed into a distillation column that allows the separation of the crude oil into different fractions depending on the difference in volatility. The pressure at the top is maintained at 1.2–1.5 ATM so that the distillation can be carried out at close to atmospheric pressure, and therefore it is known as atmospheric distillation column.

The vapours from the top of the column are a mixture of hydrocarbon gases and naphtha, at a temperature of 120 °C–130 °C. The vapor stream associated with steam used at bottom of the column is condensed by the water cooler and the liquid collected in a vessel is known as reflux drum which is present at the top of the column. Some part of the liquid is returned to the top plate of the column as overhead reflux, and the remaining liquid is sent to a stabilizer column which separates gases from liquid naphtha. A few plates below the top plate, the kerosene is obtained as product at a temperature of 190 °C–200 °C. Part of this fraction is returned to the column after it is cooled by a heat exchanger. This cooled liquid is known as circulating reflux, and it is important to controlling the heat load in the column. The remaining crude oil is passed through a side stripper which uses steam to separate kerosene. The kerosene obtained is cooled and collected in a storage tank as raw kerosene, known as straight run kerosene that boils at a range of 140 °C–270 °C. A few plates below the kerosene draw plate, the diesel fraction is obtained at a temperature of 280 °C–300 °C. The diesel fraction is then cooled and stored. The top product from the atmospheric distillation column is a mixture of hydrocarbon gases, e.g., methane, ethane, propane, butane, and naphtha vapours. Residual oil present at the bottom of the column is known as Reduced crude Oil (RCO). The temperature of the stream at the bottom is 340 °C–350 °C, which is below the cracking temperature of oil.

Simulation helps in crude oil characterization so that thermodynamic and transport properties can be predicted. Dynamic models help in examining the relationships that could not be found by experimental methods.

Petroleum products are materials derived from crude oil (petroleum) as it is processed in oil refineries. The majority of petroleum is converted to petroleum products, which includes several classes of fuels.

Oil refineries also produce various intermediate products such as hydrogen, light hydrocarbons, reformate and pyrolysis gasoline. These are not usually transported but instead are blended or processed further on-site. Chemical plants are thus often adjacent to oil refineries or a number of further chemical processes are integrated into it. For example, light hydrocarbons are steam-cracked in an ethylene plant, and the produced ethylene is polymerized to produce polyethene.

Because technical reasons and environment protection demand a very low sulphur content in all but the heaviest products, it is transformed to hydrogen sulphide via catalytic hydrodesulfurization and removed from the product stream via amine gas treating

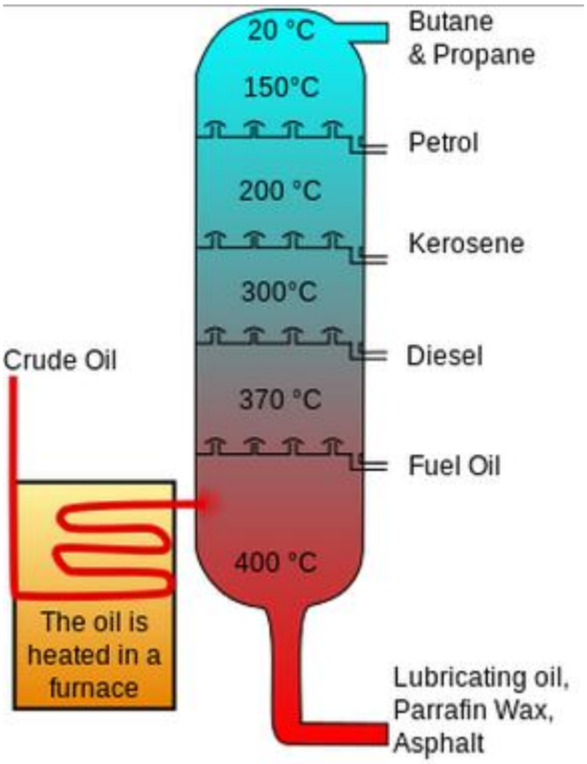

Figure 1.1: Refining of crude oiL

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Because technical reasons and environment protection demand a very low sulphur content in all but the heaviest products, it is transformed to hydrogen sulphide via catalytic hydrodesulfurization and removed from the product stream via amine gas treating. Using the Claus process, hydrogen sulphide is afterward transformed to elementary sulphur to be sold to the chemical industry. The rather large heat energy freed by this process is directly used in the other parts of the refinery. Often an electrical power plant is combined into the whole refinery process to take up the excess heat.

According to the composition of the crude oil and depending on the demands of the market, refineries can produce different shares of petroleum products. The largest share of oil products is used as "energy carriers", i.e., various grades of fuel oil and gasoline. These fuels include or can be blended to give gasoline, jet fuel, diesel fuel, heating oil, and heavier

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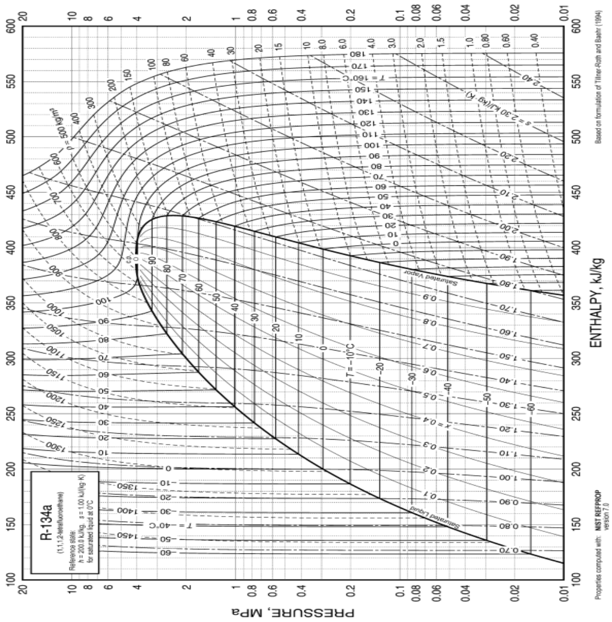
fuel oils. Heavier (less volatile) fractions can also be used to produce asphalt, tar, paraffin wax, lubricating and other heavy oils. Refineries also produce other chemicals, some of which are used in chemical processes to produce plastics and other useful materials. Since petroleum often contains a few percent sulphur-containing molecules, elemental sulphur is also often produced as a petroleum product. Carbon, in the form of petroleum coke, and hydrogen may also be produced as petroleum products. The hydrogen produced is often used as an intermediate product for other oil refinery processes such as hydrocracking and hydrodesulfurization.

Refrigerant

1,1,1,2-Tetrafluoroethane (also known as (INN), R-134a, Freon 134a, Forane 134a, Genetron 134a, Florasol 134a, Suva 134a, or HFC-134**a**) is a hydrofluorocarbon (HFC) and haloalkane refrigerant with thermodynamic properties similar to R-12 (dichlorodifluoromethane) but with insignificant ozone depletion potential and a lower 100-year global warming potential (1,430, compared to R-12's GWP of 10,900). It has the formula CF_3CH_2F and a boiling point of −26.3 °C (−15.34 °F) at atmospheric pressure. R-134a cylinders are colored light blue. A phaseout and transition to HFO-1234yf and other refrigerants, with GWPs similar to CO_2.

Figure 2: Pressure Enthalpy Diagram for Refrigerant 134a



SPECIFIC HEAT

The specific heat is the amount of heat per unit mass required to raise the temperature by one degree of Celsius. The relationship between heat and temperature change is usually expressed in the form where c is the specific heat. The relationship does not apply if a phase change is encountered, because the heat added or removed during a phase change does not change the temperature.

$Q=mc\Delta T$

Q = Heat Added
M = mass
C = specific heat
Δ T = Change in Temperature

The specific of water is 1 calorie/gram ºC =4.186 joule/gram ºC which is higher than any other common substance. As a result, water plays a very important role in temperature regulation. The specific of per gram of water is much higher than that of metal, as described in the water-metal example. For most purposes, it is more meaningful to compare the molar specific heat of substances.

Table 1.1: 1,1,1,2- Tetrafluoroethene (134a)

Refrigerant 134a (1,1,1,2-Tetrafluoroethane) Properties of Saturated Liquid and Saturated Vapor

Temp.,* °C	Pressure, MPa	Density, kg/m³ Liquid	Volume, m³/kg Vapor	Enthalpy, kJ/kg Liquid	Enthalpy, kJ/kg Vapor	Entropy, kJ/(kg·K) Liquid	Entropy, kJ/(kg·K) Vapor	Specific Heat c_p, kJ/(kg·K) Liquid	Specific Heat c_p, kJ/(kg·K) Vapor	c_p/c_v Vapor	Velocity of Sound, m/s Liquid	Velocity of Sound, m/s Vapor	Viscosity, µPa·s Liquid	Viscosity, µPa·s Vapor	Thermal Cond., mW/(m·K) Liquid	Thermal Cond., mW/(m·K) Vapor	Surface Tension, mN/m	Temp.,* °C
−103.30[a]	0.00039	1591.1	35.4960	71.46	334.94	0.4126	1.9639	1.184	0.585	1.164	1120	126.8	2175.0	6.46	145.2	3.08	28.07	−103.30
−100	0.00056	1582.4	25.1930	75.36	336.85	0.4354	1.9456	1.184	0.593	1.162	1103	127.9	1893.0	6.60	143.2	3.34	27.50	−100
−90	0.00152	1555.8	9.7698	87.23	342.76	0.5020	1.8972	1.189	0.617	1.156	1052	131.0	1339.0	7.03	137.3	4.15	25.79	−90
−80	0.00367	1529.0	4.2682	99.16	348.83	0.5654	1.8580	1.198	0.642	1.151	1002	134.0	1018.0	7.46	131.5	4.95	24.10	−80
−70	0.00798	1501.9	2.0590	111.20	355.02	0.6262	1.8264	1.210	0.667	1.148	952	136.8	809.2	7.89	126.0	5.75	22.44	−70
−60	0.01591	1474.3	1.0790	123.36	361.31	0.6846	1.8010	1.223	0.692	1.146	903	139.4	663.1	8.30	120.7	6.56	20.80	−60
−50	0.02945	1446.3	0.60620	135.67	367.65	0.7410	1.7806	1.238	0.720	1.146	855	141.7	555.1	8.72	115.6	7.36	19.18	−50
−40	0.05121	1417.7	0.36108	148.14	374.00	0.7956	1.7643	1.255	0.749	1.148	807	143.6	472.2	9.12	110.6	8.17	17.60	−40
−30	0.08438	1388.4	0.22594	160.79	380.32	0.8486	1.7515	1.273	0.781	1.152	760	145.2	406.4	9.52	105.8	8.99	16.04	−30
−28	0.09270	1382.4	0.20680	163.34	381.57	0.8591	1.7492	1.277	0.788	1.153	751	145.4	394.9	9.60	104.8	9.15	15.73	−28
−26.07[b]	0.10133	1376.7	0.19018	165.81	382.78	0.8690	1.7472	1.281	0.794	1.154	742	145.7	384.2	9.68	103.9	9.31	15.44	−26.07
−26	0.10167	1376.5	0.18958	165.90	382.82	0.8694	1.7471	1.281	0.794	1.154	742	145.7	383.8	9.68	103.9	9.32	15.43	−26
−24	0.11130	1370.4	0.17407	168.47	384.07	0.8798	1.7451	1.285	0.801	1.155	732	145.9	373.1	9.77	102.9	9.48	15.12	−24
−22	0.12165	1364.4	0.16006	171.05	385.32	0.8900	1.7432	1.289	0.809	1.156	723	146.1	362.9	9.85	102.0	9.65	14.82	−22
−20	0.13273	1358.3	0.14739	173.64	386.55	0.9002	1.7413	1.293	0.816	1.158	714	146.3	353.0	9.92	101.1	9.82	14.51	−20
−18	0.14460	1352.1	0.13592	176.23	387.79	0.9104	1.7396	1.297	0.823	1.159	705	146.4	343.5	10.01	100.1	9.98	14.21	−18
−16	0.15728	1345.9	0.12551	178.83	389.02	0.9205	1.7379	1.302	0.831	1.161	695	146.6	334.3	10.09	99.2	10.15	13.91	−16
−14	0.17082	1339.7	0.11605	181.44	390.24	0.9306	1.7363	1.306	0.838	1.163	686	146.7	325.4	10.17	98.3	10.32	13.61	−14
−12	0.18524	1333.4	0.10744	184.07	391.46	0.9407	1.7348	1.311	0.846	1.165	677	146.8	316.9	10.25	97.4	10.49	13.32	−12
−10	0.20060	1327.1	0.09959	186.70	392.66	0.9506	1.7334	1.316	0.854	1.167	668	146.9	308.6	10.33	96.5	10.66	13.02	−10
−8	0.21693	1320.8	0.09242	189.34	393.87	0.9606	1.7320	1.320	0.863	1.169	658	146.9	300.6	10.41	95.6	10.83	12.72	−8
−6	0.23428	1314.3	0.08587	191.99	395.06	0.9705	1.7307	1.325	0.871	1.171	649	147.0	292.9	10.49	94.7	11.00	12.43	−6
−4	0.25268	1307.9	0.07987	194.65	396.25	0.9804	1.7294	1.330	0.880	1.174	640	147.0	285.4	10.57	93.8	11.17	12.14	−4
−2	0.27217	1301.4	0.07436	197.32	397.43	0.9902	1.7282	1.336	0.888	1.176	631	147.0	278.1	10.65	92.9	11.34	11.85	−2
0	0.29280	1294.8	0.06931	200.00	398.60	1.0000	1.7271	1.341	0.897	1.179	622	146.9	271.1	10.73	92.0	11.51	11.56	0
2	0.31462	1288.1	0.06466	202.69	399.77	1.0098	1.7260	1.347	0.906	1.182	612	146.9	264.3	10.81	91.1	11.69	11.27	2
4	0.33766	1281.4	0.06039	205.40	400.92	1.0195	1.7250	1.352	0.916	1.185	603	146.8	257.6	10.90	90.2	11.86	10.99	4
6	0.36198	1274.7	0.05644	208.11	402.06	1.0292	1.7240	1.358	0.925	1.189	594	146.7	251.2	10.98	89.4	12.04	10.70	6
8	0.38761	1267.9	0.05280	210.84	403.20	1.0388	1.7230	1.364	0.935	1.192	585	146.5	244.9	11.06	88.5	12.22	10.42	8
10	0.41461	1261.0	0.04944	213.58	404.32	1.0485	1.7221	1.370	0.945	1.196	576	146.4	238.8	11.15	87.6	12.40	10.14	10
12	0.44301	1254.0	0.04633	216.33	405.43	1.0581	1.7212	1.377	0.956	1.200	566	146.2	232.9	11.23	86.7	12.58	9.86	12
14	0.47288	1246.9	0.04345	219.09	406.53	1.0677	1.7204	1.383	0.967	1.204	557	146.0	227.1	11.32	85.9	12.77	9.58	14
16	0.50425	1239.8	0.04078	221.87	407.61	1.0772	1.7196	1.390	0.978	1.209	548	145.7	221.5	11.40	85.0	12.95	9.30	16
18	0.53718	1232.6	0.03830	224.66	408.69	1.0867	1.7188	1.397	0.989	1.214	539	145.5	216.0	11.49	84.1	13.14	9.03	18
20	0.57171	1225.3	0.03600	227.47	409.75	1.0962	1.7180	1.405	1.001	1.219	530	145.1	210.7	11.58	83.3	13.33	8.76	20
22	0.60789	1218.0	0.03385	230.29	410.79	1.1057	1.7173	1.413	1.013	1.224	520	144.8	205.5	11.67	82.4	13.53	8.48	22
24	0.64578	1210.5	0.03186	233.12	411.82	1.1152	1.7166	1.421	1.025	1.230	511	144.5	200.4	11.76	81.6	13.72	8.21	24
26	0.68543	1202.9	0.03000	235.97	412.84	1.1246	1.7159	1.429	1.038	1.236	502	144.1	195.4	11.85	80.7	13.92	7.95	26
28	0.72688	1195.2	0.02826	238.84	413.84	1.1341	1.7152	1.437	1.052	1.243	493	143.6	190.5	11.95	79.8	14.13	7.68	28
30	0.77020	1187.5	0.02664	241.72	414.82	1.1435	1.7145	1.446	1.065	1.249	483	143.2	185.8	12.04	79.0	14.33	7.42	30
32	0.81543	1179.6	0.02513	244.62	415.78	1.1529	1.7138	1.456	1.080	1.257	474	142.7	181.1	12.14	78.1	14.54	7.15	32
34	0.86263	1171.6	0.02371	247.54	416.72	1.1623	1.7131	1.466	1.095	1.265	465	142.1	176.6	12.24	77.3	14.76	6.89	34
36	0.91185	1163.4	0.02238	250.48	417.65	1.1717	1.7124	1.476	1.111	1.273	455	141.6	172.1	12.34	76.4	14.98	6.64	36
38	0.96315	1155.1	0.02113	253.43	418.55	1.1811	1.7118	1.487	1.127	1.282	446	141.0	167.7	12.44	75.6	15.21	6.38	38
40	1.0166	1146.7	0.01997	256.41	419.43	1.1905	1.7111	1.498	1.145	1.292	436	140.3	163.4	12.55	74.7	15.44	6.13	40
42	1.0722	1138.2	0.01887	259.41	420.28	1.1999	1.7103	1.510	1.163	1.303	427	139.7	159.2	12.65	73.9	15.68	5.88	42
44	1.1301	1129.5	0.01784	262.43	421.11	1.2092	1.7096	1.523	1.182	1.314	418	138.9	155.1	12.76	73.0	15.93	5.63	44
46	1.1903	1120.6	0.01687	265.47	421.92	1.2186	1.7089	1.537	1.202	1.326	408	138.2	151.0	12.88	72.1	16.18	5.38	46
48	1.2529	1111.5	0.01595	268.53	422.69	1.2280	1.7081	1.551	1.223	1.339	399	137.4	147.0	13.00	71.3	16.45	5.13	48
50	1.3179	1102.3	0.01509	271.62	423.44	1.2375	1.7072	1.566	1.246	1.354	389	136.6	143.1	13.12	70.4	16.72	4.89	50
52	1.3854	1092.9	0.01428	274.74	424.15	1.2469	1.7064	1.582	1.270	1.369	379	135.7	139.2	13.24	69.6	17.01	4.65	52
54	1.4555	1083.2	0.01351	277.89	424.83	1.2563	1.7055	1.600	1.296	1.386	370	134.7	135.4	13.37	68.7	17.31	4.41	54
56	1.5282	1073.4	0.01278	281.06	425.47	1.2658	1.7045	1.618	1.324	1.405	360	133.8	131.6	13.51	67.8	17.63	4.18	56
58	1.6036	1063.2	0.01209	284.27	426.07	1.2753	1.7035	1.638	1.354	1.425	350	132.7	127.9	13.65	67.0	17.96	3.95	58
60	1.6818	1052.9	0.01144	287.50	426.63	1.2848	1.7024	1.660	1.387	1.448	340	131.7	124.2	13.79	66.1	18.31	3.72	60
62	1.7628	1042.2	0.01083	290.78	427.14	1.2944	1.7013	1.684	1.422	1.473	331	130.5	120.6	13.95	65.2	18.68	3.49	62
64	1.8467	1031.2	0.01024	294.09	427.61	1.3040	1.7000	1.710	1.461	1.501	321	129.4	117.0	14.11	64.3	19.07	3.27	64
66	1.9337	1020.0	0.00969	297.44	428.02	1.3137	1.6987	1.738	1.504	1.532	311	128.1	113.5	14.28	63.4	19.50	3.05	66
68	2.0237	1008.3	0.00916	300.84	428.36	1.3234	1.6972	1.769	1.552	1.567	301	126.8	109.9	14.46	62.6	19.95	2.83	68
70	2.1168	996.2	0.00865	304.28	428.65	1.3332	1.6956	1.804	1.605	1.607	290	125.5	106.4	14.65	61.7	20.45	2.61	70
72	2.2132	983.8	0.00817	307.78	428.86	1.3430	1.6939	1.843	1.665	1.653	280	124.0	102.9	14.85	60.8	20.98	2.40	72
74	2.3130	970.8	0.00771	311.33	429.00	1.3530	1.6920	1.887	1.734	1.705	269	122.6	99.5	15.07	59.9	21.56	2.20	74
76	2.4161	957.3	0.00727	314.94	429.04	1.3631	1.6899	1.938	1.812	1.766	259	121.0	96.0	15.30	59.0	22.21	1.99	76
78	2.5228	943.1	0.00685	318.63	428.98	1.3733	1.6876	1.996	1.904	1.838	248	119.4	92.5	15.56	58.1	22.92	1.80	78
80	2.6332	928.2	0.00645	322.39	428.81	1.3836	1.6850	2.065	2.012	1.924	237	117.7	89.0	15.84	57.2	23.72	1.60	80
85	2.9258	887.2	0.00550	332.22	427.76	1.4104	1.6771	2.306	2.397	2.232	207	113.1	80.2	16.67	54.9	26.22	1.14	85
90	3.2442	837.8	0.00461	342.93	425.42	1.4390	1.6662	2.756	3.121	2.820	176	107.9	70.9	17.81	52.8	29.91	0.71	90
95	3.5912	772.7	0.00374	355.25	420.67	1.4715	1.6492	3.938	5.020	4.369	141	101.9	60.4	19.61	51.7	36.40	0.33	95
100	3.9724	651.2	0.00268	373.30	407.68	1.5188	1.6109	17.59	25.35	20.81	101	94.0	45.1	24.21	59.9	60.58	0.04	100
101.06[c]	4.0593	511.9	0.00195	389.64	389.64	1.5621	1.5621	∞	∞	∞	0	0.0	—	—	∞	∞	0.00	101.06

*Temperatures on ITS-90 scale [a]Triple point [b]Normal boiling point [c]Critical point

3

3.Calculations:

Design of cooling systems for these 3 heat exchangers.
How much heat energy to be removed per liter distillation?
How much is the quantity of refrigerant required per liter distillation?
How much is the power of compressor per liter distillation?
For Heat exchanger extracting Naphtha –: -
$\Delta T = 100 - 30 = 70$ C
m= Mass flow rate of refrigerant, depends on which ref we choose
Cp = Depends on refrigerant we choose.
Let's assume, we choose, Tetraflouroethane (R 134A) as refrigerant.
R 134 A refrigerant enters the coil at -26.07 and leaves the coil at +20 C
Enthalpy of refrigerant at liquid state while entering the coil = 165.81 KJ/Kg
Enthalpy of refrigerant at Vapor state while leaving the coil = 409.75 KJ/Kg

Net heat absorption capacity = 409.75-165.81= 243.94 KJ/KG
Assume this much heat is removed in the coil per second.

$Q = m*Cp*\Delta T =$
243.94 = m * 1.281 * {20-(-26.07)}
T = Temperature at which Naphtha gets evaporated = Temperature of the refrigerant leaving the coil. = 90 C based on data of the Heavy and Light Naphtha boiling points at atmospheric pressure. However, we are decreasing the pressure, so that even Heavy naphtha will have boiling point of 90 C
Thus, temperature of the refrigerant leaving the evaporator coil = 90 C
243.94= m *1.281*(20+26.07) = 4.13 kg/s
Flow rate of the Crude Oil components passing through the solenoid valves:
243.94 =m * Cp for Naphtha * (90-20) For first coil
243.94 =m* Cp for Petrol and LPG* (120-20) For second coil
243.94 = m* Cp for Kerosene and diesel* (200-20) For third coil.
Mass flow rate of Naphtha In first coil:
$C_{p\text{- Naphtha}}$ = 165.48 J/Mol K
1 Kg of Naphtha have how many moles?
molecular weight = 145 g/mol
= 165.48/145 J/g-K
Cp = 1.14 J/gk = 1.14 KJ/KgK
Mass flow rate of Naphtha:
m = 3.05 Kg/s
Cp of Petrol = 2.22
243.94 = m_{Petrol} * 2.22 *100
m = 1.09 Kg/s
243.94 = m * 2.01 * 180
m = 0.67 kg/s

4.RESULTS AND DISCUSSION

Mass flow rate of the Naphthalene = 3.05 kg/s
Mass Flow rate of Petrol = 1.09 Kg/s
Mass Flow rate of Diesel/Kerosene = 0.67 Kg/s

Total Quantity of Refrigerant = 4.13 Kg/s

Temperature of the refrigerant at Condenser = 90 C
Temperature of the refrigerant at each Evaporator coil = -29.06 C
Flow rate at condenser coil = 12.39 kg/s
Flow rate at each evaporator coil = 4.13 Kg/s
Heat removed from Naphtha = 243.94 *3.05 = 741.57 KJ/s
Heat Removed from Petrol = 243.94*1.09 = 265.89 KJ/s
Heat removed from Diesel = 243.94*0.67 = 163.43 KJ/s
Total Heat of the system = 1170.91 KJ/s

After finding out the heat removed from naphtha, petrol and diesel from there we can find the total heat removed from the system after adding the total net quantity of refrigerant in the system. The temperature at condenser is 90ºC and at evaporator is -29.06ºC. From there we can calculate the mass flow rate of condenser and evaporator coil. After finding out the flow rate condenser and evaporator coil, we can find the mass flow rate of Naphtha, Petrol and Kerosene/Diesel. From there we can find out how much amount of crude oil is being eliminated and separated by distillation method by calculating the mass flow rate of different forms of crude oil.

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