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Preheat Network Reconfiguration of Kero Hydrodesulphurization Unit

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Abstract - *The project is based on the reconfiguration of feed preheat network in a Kero Hydro Desulphurization unit. This reconfiguration is beneficial as it does not require additional equipment to raise the feed temperature. Hydrodesulphurization is a catalytic process typically used in the Oil & Gas Refining industry to remove sulphur from natural gas and refined petroleum products. In the past, feed was charged from the Crude Distillation Unit at 103⁰C. Due to the shutdown of the CDU, the feed is now charged from storage tanks at a temperature of 40⁰C. This calls for a higher feed heater duty or a reduction in feed rate. This potential underutilization of the unit can impact the product supply from the refinery with negative financial implications. The objective is to preheat the feed at a temperature of 40⁰C to the existing feed temperature level of 103⁰C. The course of action was to configure the heat exchanger network of the unit in Aspen - Hysys as existing to validate the exchanger design with present operating condition and to reconfigure the same exchanger network and reroute the heating streams to maximise the feed temperature, whilst ensuring sufficient temperature availability at the fractionator inlet for the required performance. Based on the simulation study, the feed preheat network was successfully reconfigured as it raised the feed to the desired temperature level as well as reduced the charge heater duty while maintaining the required fractionator feed temperature at an optimum level.*

Key Words: Heat exchanger, Hydro Desulphurization, Aspen Hysys, Preheat Network, Reconfiguration.

1.INTRODUCTION

Kerosene Hydro Desulphurization is a catalytic process carried out to convert the Sulphur present in the kerosene into hydrogen sulphide by hydrotreating at very high temperatures. The purpose of the unit is to desulphurize the kerosene to make specialty products of higher purity like Aviation Turbine Fuel, Jet Propulsion Fuel and Mineral Turpentine Oil. The desulphurisation of kerosene is accomplished by the hydrogenation of various sulphur compounds in the kerosene cut to hydrogen sulphide and a hydrocarbon. The hydrogenation is carried out in presence of a catalyst. The hydrogen sulphide is later stripped off from the kerosene by fractionation. The process primarily employs a charge furnace, a reactor, hydrogen separator, stabilizer fractionators, amine absorber and hydrogen recycle gas compressor.

The Kerosene Hydro Desulfurizing unit in BPCL - KR is originally designed by Phillips Petroleum Company in 1966 to process the raw kerosene drawn from crude unit so that the finished kerosene meets all the product quality requirements for Indian grade superior kerosene. The unit design capacity is 57 tonnes/hour but normally processes 60 tonnes/hour of raw kerosene from the crude unit.

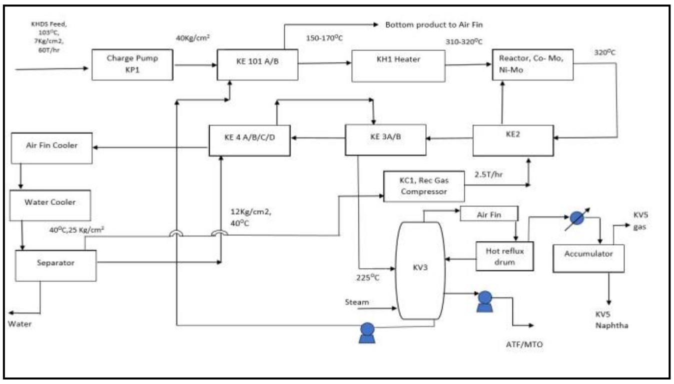
The major products produced from the unit are either Diesel, ATF or MTO. The heavy Desulphurized Kerosene fraction obtained from fractionator column bottom is normally blended to diesel product. BPCL desires to revamp the existing preheat network of the unit to increase the inlet feed temperature, thereby reducing the fired duty of the feed heater KH1. KHDS unit is a part of CDU I block and at the present operating scenario, kerosene feed is available at a temperature of around 103⁰C from Crude distillation Unit1. Due to the envisaged changes in refinery operation plan, the feed will now be obtained from storage tanks at a temperature of 35 - 40⁰C. The objective of the reconfiguration process is to preheat the KHDS feed received at a temperature of around 40⁰C to the existing feed temperature level as a least by reconfiguring the existing heat exchangers network so that it does not increase the duty of the fired heater for heating the feed in the unit. Attempt is made to maximize the preheat temperature to reduce the duty of the fired heater as well to conserve energy.

2. PROCESS DESCRIPTION

The KHDS unit consist of a reactor and fractionator system. The reactor charge is passed through KE101 A/B where it exchanges heat from KV3 bottom /KV3 Side Reflux and then goes to HDS charge heater (KH1B), where it is heated to 320 – 340 ⁰C. Then, it is combined with hydrogen recycle and passed through the reactor (KV1). The reactor section consists of one fixed bed reactor of Cobalt – Molybdenum catalyst. In the reactor, the feed is being desulphurized. Objective is to achieve kerosene boiling range product specifications with less than 200 ppmwt total Sulphur and 10 ppm total Nitrogen. The reactor effluent is cooled, condensed and then fed to separator (KV2) where it is flashed from the kerosene along with a small amount of other light gases. The hydrogen is recycled back to the recycle compressor with part of it going to the fuel gas system. A part of the KV2 Gases passes through Amine Absorption unit before being recycled to the reactor. The Amine Absorption Unit in KHDS Unit is designed to absorb H2S from KV1 Recycle gas (KV2 Sour Gas) using Diethanol Amine Solution as Absorption medium. CO2 can also get absorbed along with H2S in DEA Solution, if present.

The kerosene product is then charged to kerosene fractionator (at 6th tray) after getting heated up through reactor effluents in exchangers KE4 and KE3. The fractionator (KV3) strips the residual H2S, hydrogen and light hydrocarbons from kerosene and yields overhead the naphtha produced in the desulfurization reaction. The normal top temperature and pressure are maintained at 140^{0}C and 1kg/cm^2. The desulfurized kerosene is yielded from the fractionator side draw (KV6) where it is stripped with steam. For ATF the Side Draw is taken from 16th & 18th tray and for MTO the draw is taken from 26th & 28th tray. This stream, after cooling in air fin cooler and trim cooler is sent to storage (ATF/MTO). A stream of heavy ends is yielded from the bottom of the fractionator which can also be routed to ATF or LSCD depending on product requirement.

Fig -1: Process Block Diagram



2.2 Problem Definition

The problem identified in the Kero Hydro Desulphurisation Unit is the reduction in preheat temperature of feed that can potentially reduce the unit throughput rate due to heater limitation. Currently feed is available at 103^{0}C. Due to the upcoming shutdown of CDU 1, the new feed will be available from the storage tanks at a feed temperature of 40^{0}C. The heater in use presents a limitation as it cannot preheat the feed received at 40OC to the required reactor inlet temperature. Since this scenario calls for a higher fired duty in feed heater (as the outlet temperature requirement is fixed at a temperature of 320^{0}C – 330^{0}C) a reduction in feed rate maybe required as the fired duty of heater is fixed. This potential underutilization of the unit can impact the product supply from the refinery with negative financial implications

3. METHODOLOGY

In order to carry out the simulation, the distillation data of each stream are taken from available actual plant test run data. For KHDS feed, the distillation data was directly available from the unit. Since KE3 and KE4 are the major exchangers for exchanging heat between Reactor effluent stream and the feed to fractionator, the fractionator feed (Separator liquid) stream data was essential. Since this stream data was not available, the property data of products from fractionator has been blended and the blended property has been used for simulating the KE3/KE4 Heat exchanger (The aspen simulation details are given below). The properties of the product from fractionator have been taken from actual plant test run data. The same methodology was used for generating reactor effluent stream also by blending (in simulation) the above streams with recycle gas. The stream data used for simulation are given below.

Table -1: Distillation Data

Distillation	KHDS Feed	KV5 Naphtha	Ke10 O/L	KV3 Bottom	Reactor Effluent	KE4/ KE3 Shell
IBP	145	57	152	181	-202.7	129
5%	160	102	158	193	-174.8	161
10%	162	105	160	195	-144.6	167
20%	168	108	163	200	145.3	175.5
40%	181	113	172	211	177.1	188
50%	188	115	177	217	184.5	192.7
70%	206	121	188	230	203.9	212
90%	232	132	209	248	228.9	233
95%	243	139	213	257	242.2	245
FBP	263	160	233	274	257.3	264.5

Table -2: Sample Table format

Component Mole %	KV2 GAS	KV5 GAS
H_2S	0.9	23.5
H_2	88.9	29.9
C_1	5.9	16.9
C_2	0.8	12
C_3	0.2	7.7
IC_4	Nil	1.6
NC_4	Nil	0.9
Component Mole %	KV2 GAS	KV5 GAS
O_2	0.3	0.5
N_2	3.0	7

The Fractionator feed stream distillation data is obtained by blending KV3 bottom, KV5 Naphtha, KE10 Outlet and KV5 gas. The blend stream is as follows.

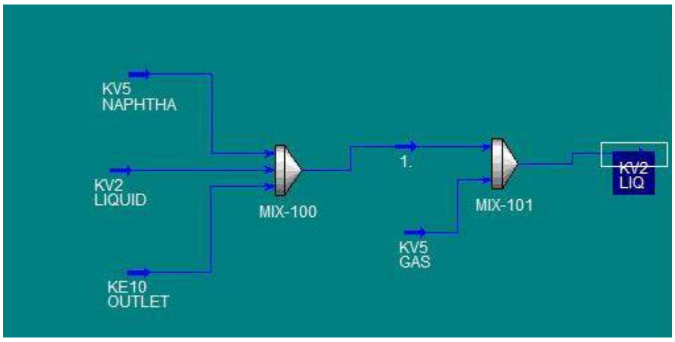


Fig -2: Fractionator feed blend stream

The Reactor effluent distillation data was obtained by blending KV3 bottom, KV5 Naphtha, KE10 Outlet and KV2 gas. The blend stream is as follows.

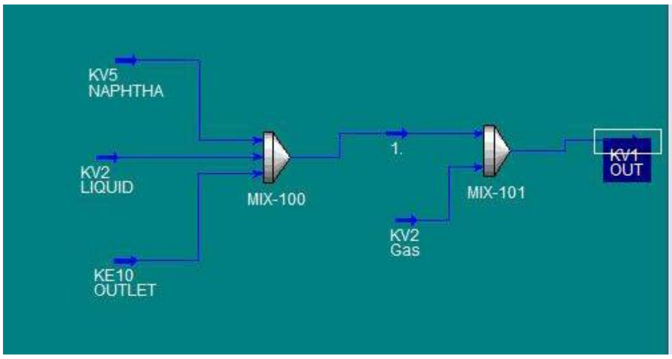


Fig -3: Reactor Effluent blend stream

The heat exchangers used in the reconfiguration study are those present in the existing unit itself. The mechanical design condition of these exchangers has been checked and confirmed for its suitability to the reconfigured network. Since the pressure rating of KE3 and KE4 exchanger are much lower to handle the charge pump discharge flow, the emphasis was to heat the feed stream to charge pump suction to the present level. A higher heat pick up (to the feed) at the charge pump suction in found not useful due to the loss of heat recovery from KV3 bottom stream to feed at pump discharge exchanger KE101. This could adversely affect the cooling requirement of KV3 bottom stream. Hence attempt was made to heat the feed stream to required level only to meet the unit's immediate requirement. The heat exchangers were built in the Rigorous Shell and Tube design using Equipment Design and Rating Software of Aspen Hysys.

The methodology followed to carry out the simulation study are as follows:

- To configure the heat exchanger network of the unit in Aspen Hysys as existing to validate the exchanger design with present operating condition.

The charge pump discharge is passed through KE101 A/B exchangers in series where it exchanges heat with fractionator stream and then goes to HDS charge heater (KH1B), where it is heated to 320^{0}C. at the existing condition the KE 101 A/B outlet temperature is around 150-170^{0}C due to availability of heat in kerosene feed to charge pump is at 110^{0}C -120^{0}C. It is then combined with hydrogen recycle and enters the reactor (KV1). The reactor effluent is cooled by exchanging heat with fractionator feed in KE3A/B and KE4 A/B/C/D exchangers which are arranged in series and is condensed and fed to separator (KV2) The condensed liquid stream is the feed to fractionator which passes through the shell side of the exchanger. The kerosene product heated through the shell side of KE3A/B and KE4 A/B/C/D is then charged to kerosene fractionator (at 6th tray).

Required fouling factor is provided to the exchanger design input so as to match the exchanger performance with actual condition. The same validated exchanger design parameters have been used for all the reconfiguration study to check the end result.

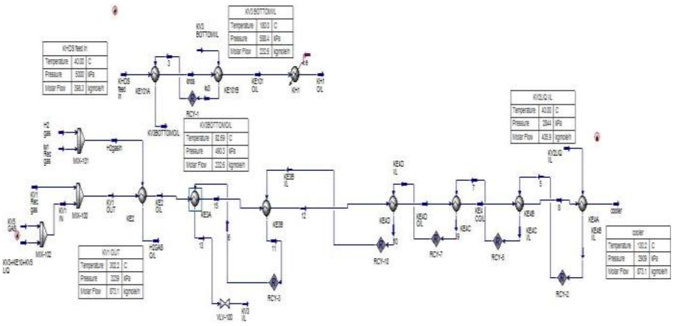


Fig -4: Existing feed preheat network

Table -3: Temperature profile of the exchanger network

Streams	Temperature (^{0}C)	Pressure (KPa)	Mass Flow (Kg/cm^2)
KHDS feed I/L	103	5000	60000
KV3 BOTTOMI/L	180	588.3991229	40000
KE101 O/L	141.7	4902	60000
KV1 OUT	302.1895	3239.454	62000
H2gasin	74.13506	3432.328	3000
H2GAS O/L	254.6844	3411.644	3000
KE2 O/L	286.6462	3198.085	62000
KV2LIQ I/L	40	2843.929	59997.11
Cooler	130.1773	2909.445	62000
Streams	Temperature (^{0}C)	Pressure (KPa)	Mass Flow (Kg/cm^2)
13	262.0307	2787.267	59997.11
KV3 I/L	226.8242	258.2314	59997.11

- Reconfigure the same exchanger network by rerouting the heating streams to maximize the feed temperature, same time ensuring sufficient temperature availability at fractionator inlet for the required fractionator performance.

In this reconfiguration, the KHDS feed kerosene from storage tanks at 40^{0}C is charged to the shell side of heat exchangers KE4 C/D where the feed is preheated to 106^{0}C using reactor effluent at the outlet of KE4 A/B. The feed is then charged into a pump and pumped upto a pressure of 40 Kg/cm^2 into heat exchangers KE101 A/B. The feed is preheated at KE101 A/B where it is heated with KV3 bottom stream to a temperature of 148^{0}C. The heated feed stream is then sent into the feed heater KH1 after which it is charged into the HDS reactor. The reactor effluent is cooled in KE2 by exchanging heat with HDS recycle gas which is sent to the reactor. The reactor effluent stream is further cooled at KE3 A/B and KE4 A/B by exchanging heat with KV2 liquid and is cooled down at KE4 C/D by exchanging heat with KHDS feed stream and is sent to an airfin cooler and trim cooler. The fractionator feed is heated and is charged into the fractionator at a temperature of 223.8^{0}C.

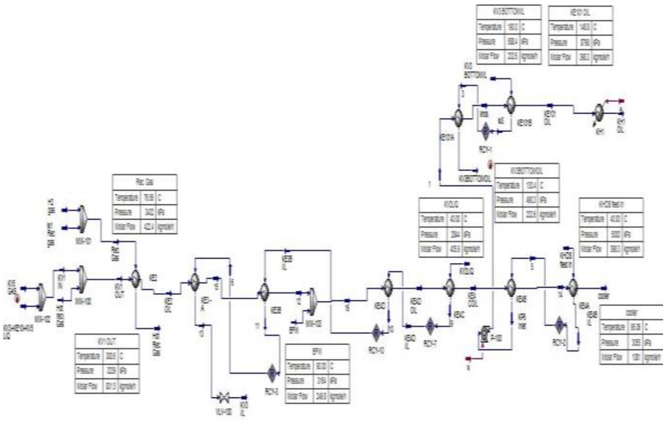


Fig -5: Reconfigured Feed Preheat Network case 1

- Reconfigure the same exchanger network by rerouting the heating streams to maximize the feed temperature, same time ensuring sufficient temperature availability at fractionator inlet for the required fractionator performance.

In this reconfiguration, the KHDS feed kerosene from storage tanks at 40^{0}C is charged to the shell side of heat exchangers KE4 A/B where the feed is preheated to 127^{0}C using reactor effluent at the outlet of KE3 A/B. The feed is then charged into a pump and pumped upto a pressure of 40 Kg/cm^{2} into heat exchangers KE101 A/B. The feed is preheated at KE101 A/B where it is heated with KV3 bottom stream to a temperature of 159^{0}C. The heated feed stream is then sent into the feed heater KH1 after which it is charged into the HDS reactor. The reactor effluent is cooled in KE2 by exchanging heat with HDS recycle gas which is sent to the reactor. The reactor effluent stream is further cooled at KE3 A/B and KE4 A/B by exchanging heat with KV2 liquid and is cooled down at KE4 C/D by exchanging heat with KHDS feed stream and is sent to an airfin cooler and trim cooler. The fractionator feed is heated and is charged into the fractionator at a temperature of 220^{0}C.

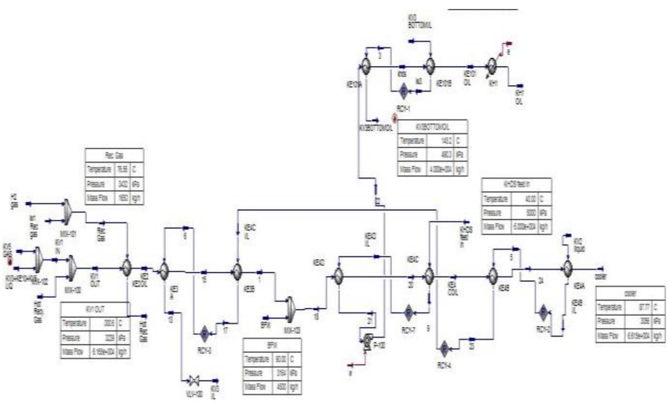


Fig -6: Reconfigured Feed Preheat Network case 2

4. RESULTS

Based on the simulation study, two cases were considered.

In the first case, preheat of feed is carried out in KE4 C/D and KE101 A/B. The temperature profile of the exchanger network is given below.

Table -4: Temperature profile of exchanger network case1

Streams	T (^{0}C)	P(KPa)	Mass Flow (Kg/cm^{2})
KHDS feed in	40	5000	60000
KV3 BOTTOMI/L	190	588.399	40000
KV3BOTTOMO/L	130.4478	490.335	60000
KE101 O/L	148.843	8797.64	62000
KP6 Inlet	105.1838	4973.04	3000
1-PumpDischarge	106.6531	8895.70	3000
KV1 OUT	300.5896	3239.45	62000
Rec. Gas	76.56424	3432.32	59997.11
13-ControlValve Inlet	253.6381	2812.92	62000
Cooler	95.06482	3054.54	59997.11
KV3 I/L	223.8287	258.231	59997.11

In this reconfiguration, the resultant heater inlet temperature and KV3 fractionator inlet was found to be 148^{0}C and 223^{0}C respectively. The disadvantage of this reconfiguration is the insufficient preheat temperature of the KHDS feed which in turn increases the heater duty. An advantage of this reconfiguration is that the fractionator inlet temperature can be maintained at 223^{0}C which is almost close to the fractionator inlet temperature maintained in the existing case.

In the second case, preheat of feed is carried out in KE4 A/B and KE101 A/B. The temperature profile of the exchanger network is given below.

Table -5: Temperature profile of exchanger network case2

Streams	T (^{0}C)	P(KPa)	Mass Flow (Kg/cm^{2})
KHDS feed in	40	5000	60000
21(Pump Suction)	126.3137	4973.10	60000
22(Pump Discharge)	127.8744	8895.77	60000
KV3 BOTTOMI/L	190	588.399	40000
KE101 O/L	159.0664	8797.71	60000
KV3BOTTOMO/L	145.2813	490.33	40000
KV1 OUT	300.6205	3239.45	61650
Cooler	88.75698	3056.38	66150
13(Control Valve Inlet)	244.7467	2812.90	59997.11
KV2 liquid	40	2843.92	59997.11
KV3 I/L	220.392	258.231	59997.11

In this reconfiguration, the only adverse consequences to the reconfiguration is the loss of temperature to the fractionator feed, since some part of heat which was supposed to heat the fractionator feed in KE4 A/B exchangers has been used for heating the KHDS feed with this configuration, the fractionator feed temperature was obtained at 220^{0}C. The feed temperature was found at 159^{0}C, which is sufficient to maintain the unit conditions as existing so that the charge rate for the unit can be maintained without increasing the duty of the fired heater.

Table -6: Data comparison

Streams	Existing	Case 1	Case 2
KH1 I/L	141.7	148.843	159.0664
KV3 I/L	226.8242	223.8287	220.392

4. CONCLUSIONS

Analyzing the various reconfiguration simulations carried out, a conclusion can be drawn considering different technical and economic aspects. The reconfiguration of the KHDS feed preheat using KE 4 C/D at the upstream of the KHDS feed charge pump and further heating the KHDS feed using KE 101 A/B up to a temperature of 159^{0}C and obtaining a sufficient temperature of 220.39^{0}C can be considered most appropriate. This configuration would reduce the charge heater duty along with maintaining the required fractionator feed temperature. This configuration requires rerouting of existing streams and does not require any additional equipment. Hence this reconfiguration of feed preheat network meets the essential requirements.

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