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Enhancing Reformate Yield on Naphtha Reforming Unit by Upgrading Secondary-Recovery Schemes

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ABSTRACT

In the oil processing industry (refinery), the process of upgrading octane number of naphtha fraction is carried out at Naphtha Reforming Unit (NRU). Some NRU scan produce high purity hydrogen gas. The high purity of hydrogen gas products correlates with the increase in yield of reformate and LPG in the NRU. Previous studies have increased the reformate yield by optimizing the reactor system, while this research is optimizing the secondary recovery system which also has an impact on reformate yield. For this purpose, a single stage contact recovery system is used in the secondary recovery system of the NRU with the addition of several other equipment. The results show that lowering the contact temperature can increase the reformate yield and product purity of hydrogen gas. From the economic analysis shows that by upgrading the basic scheme to a low temperature scheme, there must be an additional CAPEX (capital expenditure) of 4.91 M USD, and OPEX (operating expenses) of 2.26 M USD annually. Considering the 7.89 billion USD income from the additional reformate product, the investment payout period (POT) will be one year and is considered feasible.

Key words: Economics, Hydrogen, Naphtha Reforming, Refinery, Reformate

INTRODUCTION

The needs of energy in Indonesia was divided in several sectors such as Transportation, Industry, House Hold, Commercial, and other sector. Each sector has a different type of energy to be consumed, it can be fuel, electricity and others. For fuel consumption in Indonesia, Gasoline and Diesel fuel was the highest consumption. To fulfill the needs, Indonesia produce fuel and use internally but the production was lower than the consumption so the government import gasoline from outside Indonesia [1].

Fig. 1 Fuel Consumption and Fuel Import Data

Because of the production on gasoline still lower than consumption the effort to increase the production was done in the refinery to decrease the number of fuel import. Reformate was generally used as a blending component for gasoline as it has high octane number. Naphtha reforming is the unit which produce reformate. To increase the production of the

Unit, the operator can increase the heavy naphtha processing or optimizing the Unit to have higher yield. Not only to full fill the gasoline needs but also increasing yield can increase the Unit Revenue it is the reason why the optimization in NRU needs to be carried out.

Naphtha Reforming or Catalytic reforming is a one of the important unit in refinery configuration because this unit is one of gasoline component and hydrogen gas producer [2-4]. In U.S. NRU furnishes 30-40% of the gasoline requirement [5]. More than 35 Octanazing -aromazing CCR NRU has been licensed in worldwide [6–7]. This unit is able to convert virgin naphtha cuts which has low octane into reformate by reconstruction of low octane hydrocarbon component structure into more valuable high-octane gasoline components without changing the boiling point range [2, 8]. As a secondary unit in refinery, naphtha reforming is taking feed from Crude distillation unit [8]. Before the virgin naphtha going into NRU, it shall be treated to remove impurities (such as sulfur, nitrogen, metal, water, oxygen) in naphtha hydrotreater unit to protect naphtha reforming catalyst from poisoning effect [8]. Not only producing gasoline component, Naphtha reforming is also able to support the hydrogen balance of the refinery configuration because hydrogen also a desirable product in this process [2]. Hydrogen is usually used for treating unit such as Naphtha hydrotreater, diesel hydrotreater, hydrocracker, etc [2]. NRU position in refinery general configuration is shown in Fig. 2.

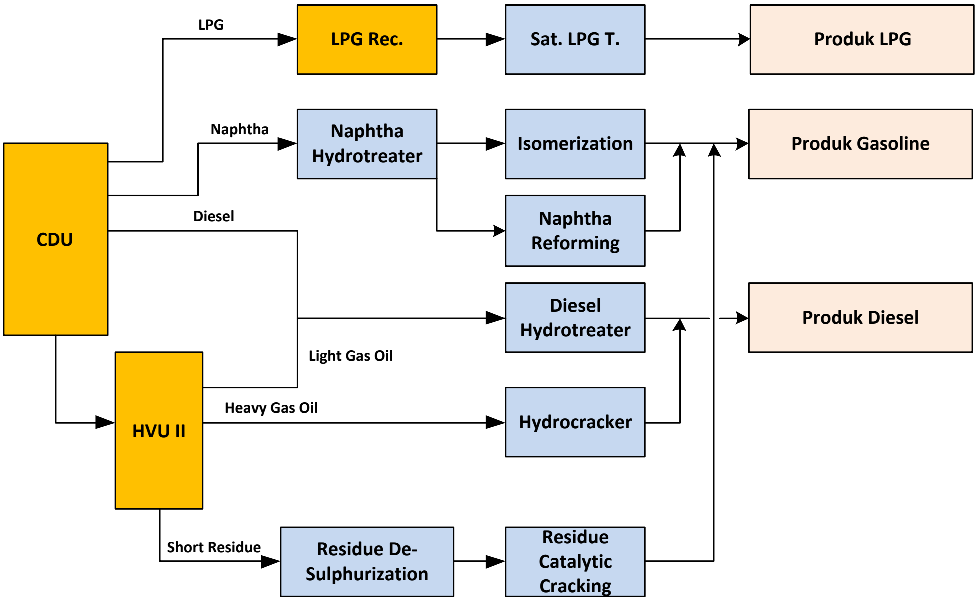

Fig. 2 NRU Position on Refinery Configuration

NRU is consisting of threesections, reactor section, secondary recovery section and stabilization section. Improvement to gain more reformate and hydrogen product was done by changing operating variable or other effort. In the reactor section, to increase the hydrogen product or yield of reformate some variable can be changed such as increasing the temperature, lowering the reaction pressure, lowering the space velocity or lowering hydrogen to hydrocarbon ratio [5]. Otaraku et al had observed that an increase in temperature lead to an increase in the concentration of hydrogen product 23.46% volume at 430°C and 51.38% volume at 540°C. a better improvement in hydrogen product also found when the refinery process Bonga crude which has different properties with Bonny crude [9]. Not only operating variable, Stijepovic et. al. investigates that changing the reactor system from conventional CCR (Continuous Catalyst Regeneration) to membrane moving bed reactor can improve 23.6 mol% in hydrogen production and 18.8 mol% in aromatics production [10].

In the secondary recovery system several innovative schemes to increase the product liquid recovery and separator gas purification have been developed. In the lower-pressure designs reactor system, where the production of C5+ material and hydrogen gas are increased as a result of more-selective processing, it is critical to increase liquid recovery [10]. The advantage of more-selective processing can be lost if a recovery system is not installed properly in downstream of the reactor section. At low operating pressures reactor system, the flash pressure of the separator has been reduced [10]. Consequently, the vapor liquid equilibrium thermodynamically allows for more butane's, propane's, and hexane+ material to leave with the vapor as a gas product, resulting in valuable C5+ product loss and lower-purity hydrogen production because of heavier component carried out with gas product. Several types of improved re-contacting schemes have been developed in order to avoid this loss [10].

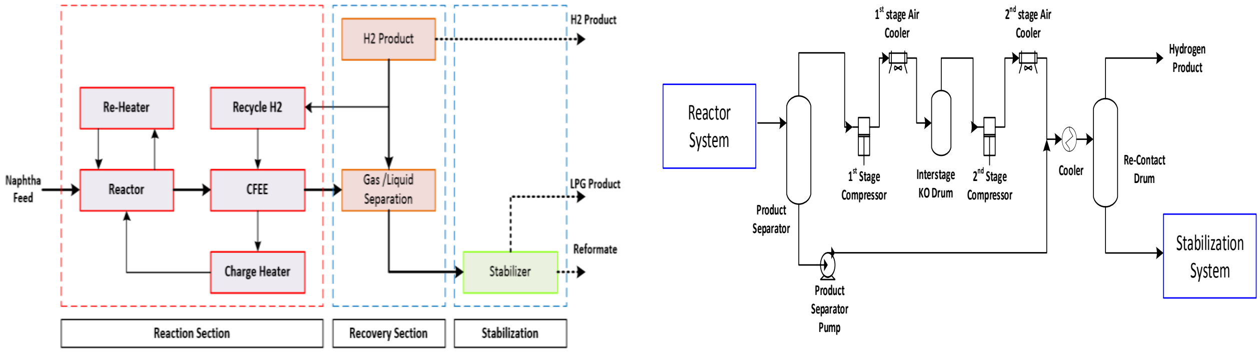

Fig. 3 Section in NRU

One scheme option is re-contacting reactor-effluent vapor-liquid system. In this scheme, after being cooled, the reactor effluent, is separated into vapor and liquid product in the two-phase separator. Some of the vapor product then is directed to the recycle-compressor suction for use as recycle gas in the reactor system and the remaining vapor, usually called the net gas (hydrogen product), will be compressed by a booster compressor and discharged into either a drum or an adsorber to remove its chloride. The liquid from the separator will be pumped to the drum to recontact with the net separator gas at high pressure then the mixture will be separated again to obtain increased liquid recovery and hydrogen purity [8]. Another method to improve the reformate yields is by chilling the net separator gas. After being cooled, the reactor effluent, is separated into vapor and liquid product in the two-phase separator. Then net gas is cooled to approximately 5°C (41°F) by using a refrigeration system. Separation of the vapor and liquid at a low temperature system can improve hydrogen purity and recovers additional liquid to stabilizer section, which would increase the reformate and LPG yield [8].

DESIGN, MATERIAL, PROCEDURE, TECHNIQUE OR METHODS

The research procedure scheme can be seen in Fig. 4.

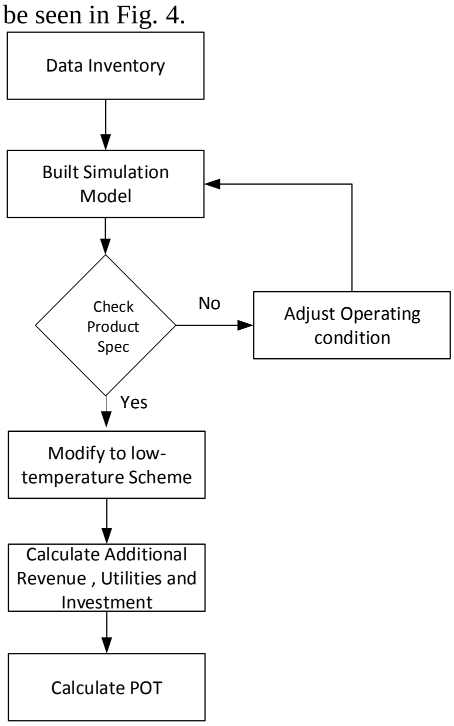

Fig. 4 Research Procedure Scheme

Fig. 4 shows the research step. This research will start with data collection and model building. The model will be built in ASPEN HYSYS V. 12. After the model was built, product gas hydrogen, LPG and reformate will be checked to make sure that the LPG fraction and reformate is well separated. LPG product will contain max. 0.2%-vol of C_{5+} component. The modification scheme will be built on the base model with modification in refrigeration system, and additional heat exchanger to save the energy. This research will extract the equipment installed price, utility consumption by using economic evaluation ASPEN HYSYS V.12. The last step will be economic evaluation by calculating additional CAPEX, OPEX, and revenue. To check that this revamp is feasible or not, POT will also be calculated.

RESULTS AND DISCUSSION

The secondary recovery model is simulate using Hysys V.12 software [11] and shown on Fig. 5.

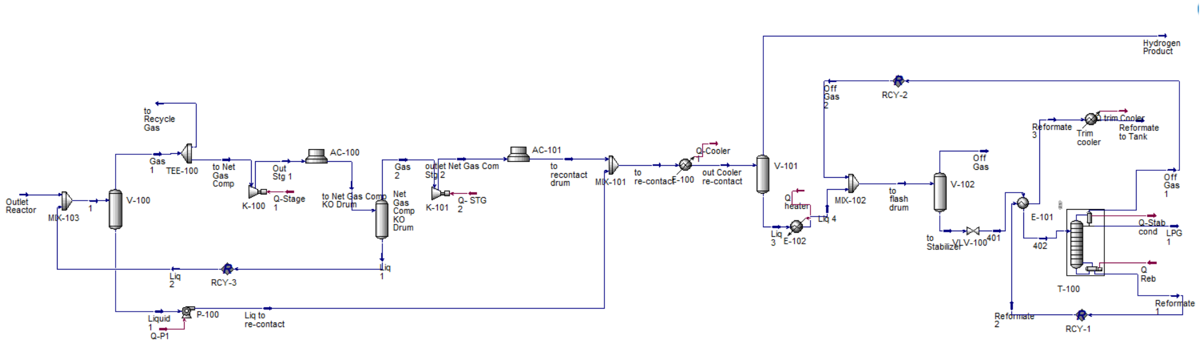

Fig. 5 Naphtha Reforming Secondary Recovery Model on Hysys V.12

Fig. 5 shows the base scheme of NRU secondary recovery system and stabilization system. In this scheme feed from reactor system will be separated into two product gas and liquid. The gas product will be compressed by two stages reciprocating compressor from operating pressure 7 kg/cm^{2}g to 40 kg/cm^{2}g. The liquid product will be pumped and mixed with compressed gas product. In the operating condition 38 ^{o}C at 40 kg/cm^{2}g, the mixture gas and liquid will be separated by two phase separator. The gas product will be sent to other process unit as hydrogen product, on the other hand the liquid product will be separated in stabilization section to gain LPG, reformate and off gas product.

Temperature Correlation to Reformate Yield

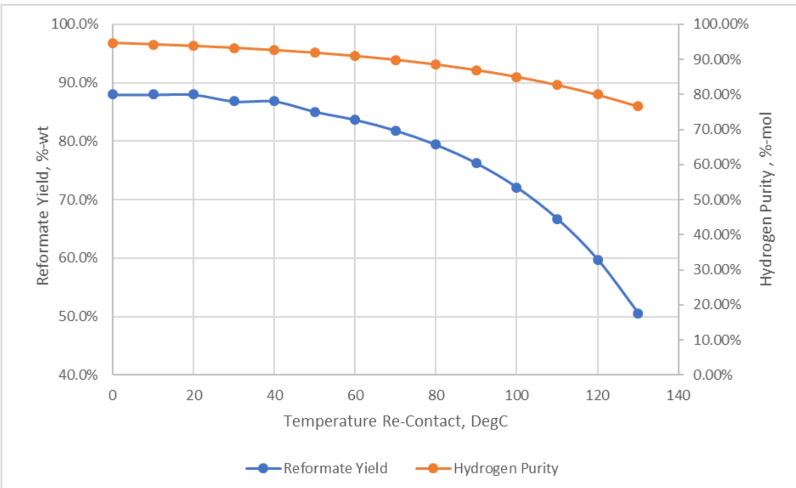

Fig. 6 Temperature Correlation to Reformate Yield and Hydrogen Purity

Based on the simulation, temperature has impact to hydrogen purity product and also Reformate yield. Lower temperature on re-contact system, higher the hydrogen purity will be. This correlation also aligns with reformate yield on, as we can see lower the temperature of recontact system, the hydrogen purity will also increase these phenomena is because the heavy component on hydrogen product is condense and going to stabilization section, therefore the reformate and LPG yield is increasing. From this correlation this research will take the lowest temperature and modify the recovery system.

Scheme Modification

Modification was done on the base scheme. The new scheme is shown on Fig. 7.

To reach the lower temperature in new scheme, refrigeration system was added. In the simulation, propane was used as the refrigerant. To optimize the energy of the system two heat exchanger also added, the first heat exchanger was added to recovery the heat on the hydrogen product because normally hydrogen gas was delivered 38 – 45 ^{o}C. The second heat exchanger was added to recovery heat for stabilization section.

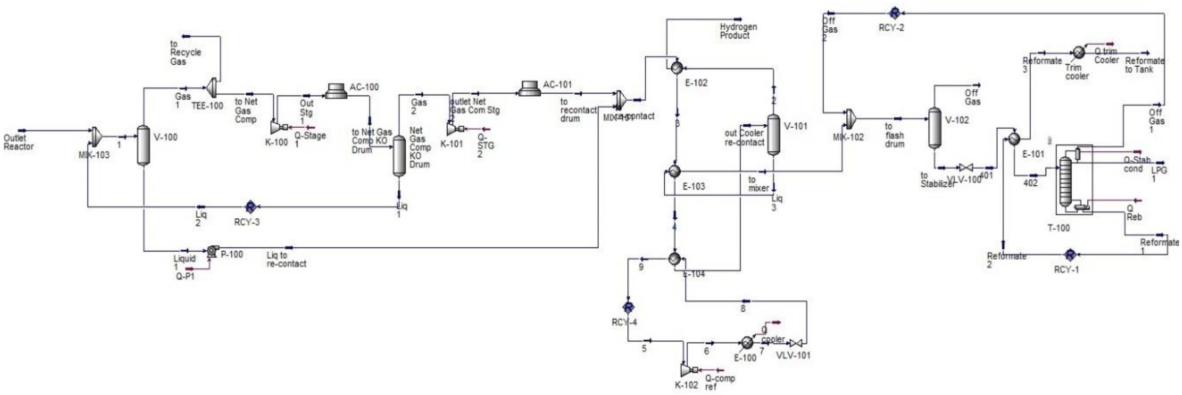

Fig. 7 Low Temperature Naphtha Reforming Secondary Recovery Modification Model

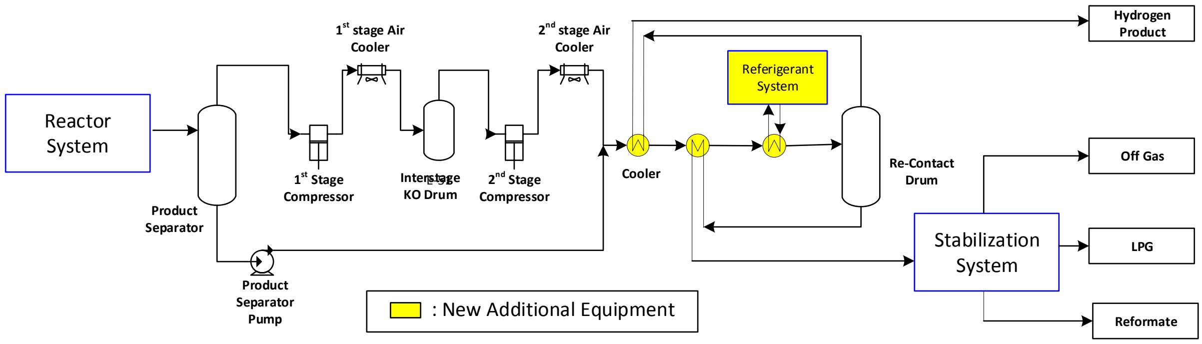

Fig. 8 Modified Low Temperature Configuration

Table - 1 Operating Condition comparation

Parameter	Unit	Base Scheme	New Scheme
Reactor System		Base	Base
Temperature Re-contact	DegC	38	0
Pressure on Re-contact System	kg/cm^2g	39.9	39.9
Temp. on Feed to Flash drum, Stabilizer System	DegC	42.94	30.78

Economic Analysis on New Scheme

From the simulation on the new scheme, the changes on material balance unit can be seen on Table -2

Table - 2 Material Balance Base and New Scheme

Parameter	Unit	Base	New Scheme
Reformate Flow	Bpd	20,101.1	20,513.5
LPG	Bpd	970.7	1,263.5
Off Gas	Nm3/day	24,530.52	22,632.13
Hydrogen Purity	%-mol	92.76%	94.66%
Hydrogen Flow	Nm^3/day	1,246,143.8	1,224,768.5

From Table -2 can be seen that changing temperature operation on re-contact scheme can increase 2.05%-vol the reformate flow, LPG product also increasing 30%-vol. on the other hand flow of hydrogen product decrease but the purity of product increasing.

In lower temperature scheme, heavy hydrocarbon on the hydrogen gas product was condense more and recovered in liquid product which sent to the stabilizer section. Additional liquid which sent to stabilizer section improve the reformate yield and LPG yield. Low temperature scheme on recontact system also improve flash drum system in the stabilization section. As we can see the off-gas produce was decreasing because of more liquid can be condensed and sent to stabilizer tower. The additional liquid sent to stabilizer tower also improve LPG and reformate yield.

In technically point of view, from the simulation can be seen that changing from base scheme to low temperature scheme give positive impact to product yield. The research will continue to economic analysis to see the additional CAPEX, OPEX and calculate how much Pay Out Time (POT) will be needed.

The economic analysis is shown on Table 3:

Table - 3 Economic Analysis

Parameter	Unit	Quantity	Remarks
Total Additional CAPEX	MUSD	4.91	
Revenue Delta Product Sales	MUSD	7.89	Reformate only
Total Annual Operating cost	MUSD	2.26	
POT	Years	5.63	

From the economic analysis can be seen that the new scheme need 4.91 MUSD additional CAPEX, and will generate 2.26 MUSD on Annual Operating Cost which consist on additional Labour Cost, Utility cost, Maintenance and repairs, Depreciation, Insurance, Plant Overhead etc. The revenue calculated on this research is only based on the reformate additional flow.

With additional CAPEX and OPEX invested for the new scheme, from economic point of view changing from Base Scheme to the Low Temperature Scheme still profitable, the POT is only 1 year and the rest operating life, the unit can gain more margin from additional reformate product.

CONCLUSION

Enhancing reformate yield in NRU can be done by changing the secondary recovery system from base scheme to low temperature system. Additional equipment shall be invested and new additional OPEX will be appeared when new scheme is installed. With the new scheme, reformate yield can be increase 2.05%, LPG product increase 30%-vol, and improving Hydrogen purity product from 92.76%-mol to 94.66%-mol. From economic analysis indicate that by upgrading the base scheme to low temperature scheme additional CAPEX of 4.91 MUSD must be invested, and an OPEX of 2.26 MUSD will appear yearly. By considering revenue 7.89 MUSD from reformate additional flow, the investment POT will be one year and is considered feasible.

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