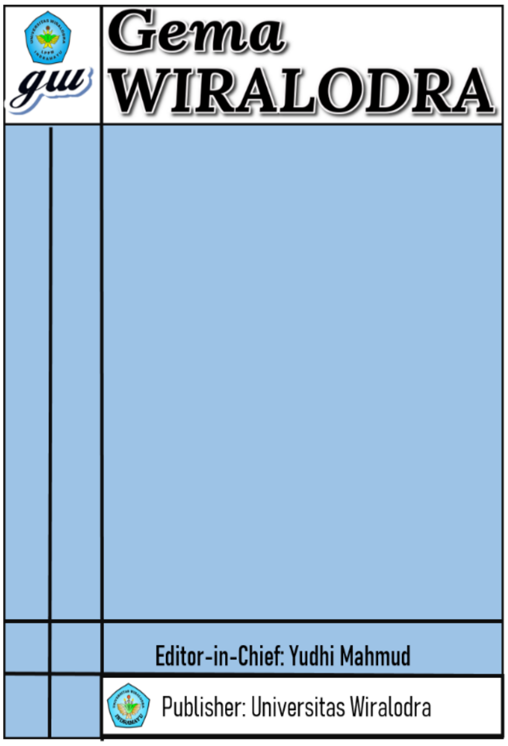
Gema Wiralodra

Publication details, including instructions for authors and subscription information:
https://gemawiralodra.unwir.ac.id



The Effect of Coke Yield on The Performance of Regenerator 15-R-103/104 in The Residue Catalytic Unit (RCU) at PT Kilang Pertamina Internasional RU VI Balongan

Ninin Asminah[a], Siti Nurkhopipah[b*], Farhan[c]

[a]Institute Technology Petroleum of Balongan, nininasminah22@gmail.com
[b*]Institute Technology Petroleum of Balongan, sitinurkhopipah70@gmail.com
[c]Institute Technology Petroleum of Balongan, mstfarhann@gmail.com

To cite this article:
Asminah, N., Nurkhopipah, S., & Farhan, F. (2025). The Effect of Coke Yield on The Performance of Regenerator 15-R-103/104 in The Residue Catalytic Unit (RCU) at PT Kilang Pertamina Internasional RU VI Balongan. *Gema Wiralodra*, *16*(3), 391 – 402.
To link to this article:
https://gemawiralodra.unwir.ac.id/index.php/gemawiralodra/issue/view/58
Published by:
Universitas Wiralodra
Jln. Ir. H. Juanda Km 3 Indramayu, West Java, Indonesia

Gema Wiralodra, 16(3), 391 – 402
https://gemawiralodra.unwir.ac.id/index.php/gemawiralodra
p – ISSN: **1693 - 7945**
e – ISSN: **2622 - 1969**

Original Article

The Effect of Coke Yield on The Performance of Regenerator 15-R-103/104 in The Residue Catalytic Unit (RCU) at PT Kilang Pertamina International RU VI Balongan

Ninin Asminah[a], Siti Nurkhopipah[b*], Farhan[c]
[a] Institute Technology Petroleum of Balongan, Indonesia, nininasminah22@gmail.com
[b*]Institute Technology Petroleum of Balongan, Indonesia, sitinurkhopipah70@gmail.com
[c] Institute Technology Petroleum of Balongan, Indonesia, mstfarhann@gmail.com
***Correspondence: sitinurkhopipah70@gmail.com**

Abstract
Regenerator 15-R-103/104 in the Residue Catalytic Unit (RCU) at PT Kilang Pertamina Internasional RU VI Balongan plays an important role in the Residue Catalytic Cracking (RCC) process by burning coke on the surface of the spent catalyst to restore catalyst activity and provide heat for the endothermic reaction. This study analyzes the effect of coke yield on regenerator performance using mass balance, heat balance, and thermal efficiency calculations based on Universal Petroleum Products (UOP) standards, with daily operational data for the period 1–28 January 2025. The results show that the total mass input of coke and combustion air is balanced with the flue gas output, indicating an efficient combustion process. The heat balance reveals a balanced energy distribution between heat carried by the flue gas, absorbed by the catalyst cooler, and lost due to radiation. The regenerator efficiency for each week was obtained at 57.98%, 58.07%, 56.13%, and 58.93%, with an average of 58%. The increase in coke yield was generally followed by an increase in the corrected heat of combustion, indicating a positive relationship between the amount of coke formed and the heat energy produced. These findings provide an important basis for optimizing regenerator performance in RCC systems.
Keywords: Coke yield, regenerator efficiency, residue catalytic unit

1. Introduction

The demand and consumption of oil and natural gas are increasing in line with the growing need for primary energy. To obtain high-quality petroleum products with greater economic value, Fluidized Catalytic Cracking (FCC) technology is being implemented. This technology converts low-value oil into products with superior specifications, quality, and sales value. At Unit VI Balongan, FCC technology is being implemented in the Residue Catalytic Unit (RCU), which utilizes residue from the AHU unit (35.5% by volume) and untreated atmospheric residue from the CDU unit (64.5% by volume) as the primary feedstock. PT Kilang Pertamina Internasional Unit VI Balongan is designed to process crude oil with a significant residual capacity, accounting for approximately 62% of the total feedstock used (Irawan & Annasit, 2023).

Regenerator Unit 15-R-103/104 at PT Kilang Pertamina Internasional RU VI Balongan functions to burn coke attached to the surface of the spent catalyst using an air supply, thus producing flue gas containing carbon monoxide (CO) and carbon dioxide (CO_2). Regenerator performance is greatly influenced by the coke yield value, namely, the amount of coke formed per unit mass of feed. A high coke yield value can increase the regenerator's workload, both in terms of air requirements for the combustion process, the resulting thermal load, and heat distribution in the dense and dilute phases (Ramadhani, 2019).

The determination of the amount of coke yield on regenerator efficiency can be analyzed by calculating the mass balance and heat balance. A mass balance is a calculation method that involves all materials entering, accumulating, and leaving a system over a certain period of time (Nelza, 2023). The main purpose of this calculation is to determine the balance between the materials entering and leaving the regenerator unit, which includes catalyst, coke, combustion air, and flue gas. Through mass balance analysis, the amount of coke burned (coke yield), the mass flow rate of the catalyst, and the amount of flue gas produced can be determined.

p – ISSN: **1693 - 7945**
e – ISSN: **2622 - 1969**

Imbalances in the mass balance can indicate disruptions in the operational process, such as leaks, material loss, or measurement errors (Smith, J.M., et al, 2018).

In line with the mass balance, the heat balance is used to describe the relationship between the incoming heat energy and the outgoing heat energy from a system based on the operating time unit (Zahidin & Rubianto, 2020). The heat balance calculation serves to determine the distribution of energy within the regenerator system. The coke combustion process on the catalyst surface produces a large amount of heat energy, which plays an important role in maintaining the stability of the operating temperature. However, not all of this energy can be utilized directly; some is absorbed by the catalyst to maintain the chemical reaction, some is carried away by the flue gas, and some is lost to the environment (Sing & Gbordzoe, 2017).

Once the two balance calculations are obtained, the next step is to determine the regenerator efficiency. This calculation aims to evaluate the extent to which the energy from coke combustion can be optimally utilized within the system. Thus, the combination of mass and heat balance analysis provides a comprehensive picture of the material and energy balances within the regenerator system. This information is crucial for evaluating unit performance, optimizing the process, and identifying potential material and energy losses that could impact the overall system efficiency.

2. Method

Data Collection

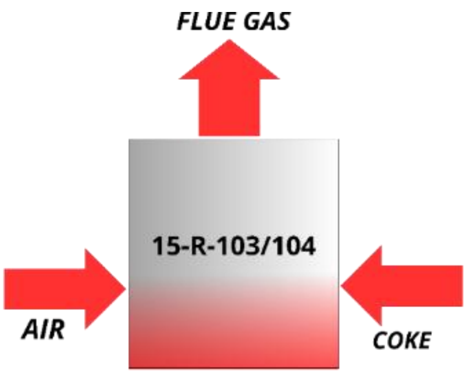
The research was carried out using a quantitative method and the data were obtained from the Regenerator 15-R-103/104 log sheet. To evaluate the performance of the regenerator, it is necessary to carry out mass and heat balance calculations and assess the regenerator’s efficiency. A correlation analysis between the yield and the regenerator's performance (ΔH Combustion Corrected) is also required. The data were obtained over a period of four consecutive weeks from 1 - 29 January 2025.

Analysis Data

To achieve the performance of the 15-R-103/104 regenerator, one method that can be used is to perform mass and heat balance calculations in accordance with the standards set by Universal Oil Products (UOP) (Pertamina EXOR-1, 1992).

Figure 1.

Regenerator Mass Balance (Pertamina EXOR-1, 1992)

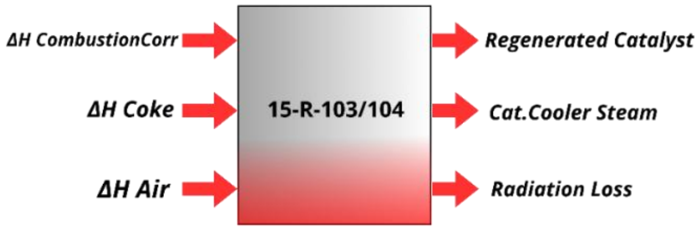


 p – ISSN: **1693 - 7945**
e – ISSN: **2622 - 1969**

Based on Figure 1, the mass entering the regenerator consists of air and coke which react through a combustion process, producing flue gas as output. Since the law of conservation of mass applies, the total mass entering the system is equals to the total mass leaving, and the mass balance equation can be written as: $W_{air} + W_{coke} = W_{fuel\ gas}$

Figure 2**.**

Regenerator Heat Balance (Pertamina EXOR-1, 1992)



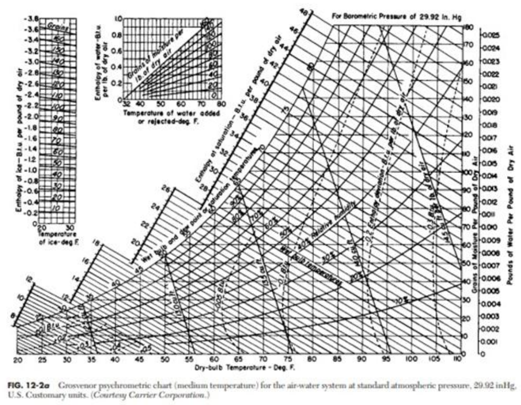
Based on Figure 2, the heat balance in the regenerator is shown as the heat input equals the heat output. The heat input includes the heat from the air, the heat for heating the coke, and the total heat of combustion of the coke after hydrogen correction. After determining the mass and heat balance, the next step in calculating efficiency can be formulates as follows:

1. Calculating water vapor content

   The water vapor content in the air can be determined by plotting known temperature and humidity data using psychometric graphs.

Figure 3.

Psychometric Graph (Perry, R.H., and Green, 1997).



2. Calculating total amount of air entering the regenerator

   Q_{wetair}= Main Air to 2nd Stage Regenerator + Main Air to 1st Stage Regenerator+ Fluffing Air to 1st Stage Regenerator x 1000 + Air flow to Regen from Catalyst Cooling Vessel+ Lance Air to Catalyst Cooler E-113A + Lance Air to Catalyst Cooler E-113B + Lance Air to Catalyst Cooler E-113C + Lance Air to Catalyst Cooler E-113D - Flow to Silencer downstream of FC034

3. Calculating regenerator inflow mass (mass flow)

$$W_{wet\ air} = air\ flow \times 1.295$$

p – ISSN: **1693 - 7945**
e – ISSN: **2622 - 1969**

4. Calculating conversion to wet air to dry air

$$W_{(dry)\ (water)} = \frac{Wwet\ air}{1+C1}$$

5. Convert air flow to molar flow basis

$$n_{(dry)\ (water)} = \frac{Wdry\ air}{MW\ Air}$$

6. Calculating mole of H_2O in wet air

$$n_{(water)\ (in)} = \frac{Wdry\ air\ x\ C1}{MW\ H2O}$$

7. Calculating molar flow of flue gas

$$n_{fluegas} = \frac{79\ x\ n_{dry\ air}}{\left(1+\frac{C2}{100}\right)\ x\ FGC_N}$$

8. Calculating mole of carbon in flue gas

$$n_{carbon} = n_{flue\ gas}\ x\ \frac{(FGC_{CO} + FGC_{CO2})}{100}$$

9. Calculating mol O_2 entering the regenerator

$$n_{O2\ to\ regen} = 21/100\ x\ n_{dry(air)}$$

10. Calculating mol O_2 in flue gas

$$n_{(O2\ in\ flue\ gas)} = n_{flue\ gas}\ x\ \frac{(FGC_{O2}+Ar-(\frac{C2}{100}xFGC_n))}{100}$$

11. Calculating mol O_2 used to form CO

$$n_{O2\ in\ CO} = 0.5\ x\ n_{fluegas} x\ \left(\frac{FGC_{CO}}{100}\right)$$

12. Calculating moles of O_2 that form CO_2

$$n_{O2\ in\ coke} = n_{(flue)\ (gas)} x\ \left(\frac{FGC_{CO2}}{100}\right)$$

13. Calculating mole of H_2O from coke combustion

$$nwater\ from\ coke = (n_{(O2\ to\ reg)\ (en)} - (n_{(O)\ (2\ in\ flue\ gas)} + n_{(O2\ in\ CO)} + n_{(O2\ in\ CO2)})\ x\ 2$$

14. Calculating coke Production

$$W_{coke} = (n_{(water)\ (from\ coke)} x\ MW_{H2}) + (n_{carbon} x\ MW_C)$$

15. Calculating yield coke

$$Yield\ Coke = \frac{Wcoke/\ 1000}{Raw\ oil\ feed}\ x\ 100\%$$

16. Calculating Hydrogen in coke

$$H_2 in\ coke = \frac{n_{water\ from\ coke}\ xMW_{H2}}{W_{Coke}}$$

17. Calculating Air : coke ratio

$$Air\ to\ coke = \frac{W_{dry\ air}}{W_{coke}}$$

18. Calculating Heat of combustion of CO

$$\Delta H_{CO} = n_{(O2\ in\ coke)} x\ 2\ x(a_1 x T_{reg} + b_1)$$

19. Calculating Heat of Combustion of CO_2

$$\Delta H_{CO2} = n_{(O2\ in\ coke)} x\ (a_2 x T_{(reg)} + b_{(2)})$$

20. Calculating Heat of combustion H_2O

$$\Delta H_{H2O} = n_{water(from\ coke)}(a_3 x T_{reg} + b_3)$$

21. Calculating Heat required heat of combustion of total coke

$$\Delta H_{Combustion} = \frac{\Delta H_{CO} + \Delta H_{CO2} + \Delta H_{H2O}}{W_{Coke}}$$

22. Calculating Correction H_2 for total coke heat of combustion

$$\Delta H_{CombustionCorr} = \Delta H_{(Combustion)} + (2636 - 314\ x\ H_2 in\ coke)$$

23. Calculating Preheating of combustion air

p – ISSN: **1693 - 7945**
e – ISSN: **2622 - 1969**

$\Delta H_{Water}=\frac{W_{dry\ air}\, x(\,Treg-Tair\ in)xCp_{air}}{W_{Coke}}$

24. Calculating Heat to heat H_2O (vapor)

$\Delta H_{H2O(Vapor)}=\frac{n_{waterin}\, x\ MW_{H2O}xCP_{H2O}x(\,Treg-Tair\ in)}{W_{Coke}}$

25. Calculating Heat required to heat coke

$\Delta H_{Coke} = Cp_{Coke}x\ (T_{reg}\text{- }T_{(rx)})$

26. Calculating Catalyst cooler heat load

$$Q_{cooler} = \Big(\big(steam_{prod} \times enthalpy_{steam} - enthalpy_{BFW}\big) + \big(BD \times enthalpy_{BD} - enthalpy_{BFW}\big)\Big) \times 100$$

27. Calculating Heat lost from catalyst cooler

$\Delta H_{Catcooler}=\frac{Q_{Cooler}}{W_{Coke}}$

28. Calculating Regenerator heat balance

Using the average regenerator heat loss of 250 BTU/lb, 250 BTU/LB x 1.055 kj/BTU x 2.20462 lb/Kg = 581.47 Kj/Kg. So, the heat used to heat the catalyst (Heat Balance):

$\Delta H_{Regen}= \Delta H_{Combustion}$ - $(\Delta H_{air} + \Delta H_{H2OVapour} + \Delta H_{\ coke} + \Delta H_{Removed} + 581.47$

29. Calculating Catalyst circulation rate

$CCR =\frac{W_{Coke}\ x\ \Delta H_{Regen}}{CP_{Cat}\ x\ (T_{Reg}-T_{Rx})}$

30. Calculating Catalyst oil ratio

$C/O\ Ratio =\frac{CCR}{FF}$

31. Calculating Delta Coke

$\Delta Coke\ \%= \frac{W_{Coke}}{CCR}\ x\ 100$

32. Calculating Regenerator Efficiency

$EFF= \frac{\Delta H\ Regenerator}{\Delta H\ Combustion\ Corr}\ x\ 100$

3. Results and Discussion

Working Principle of Regenerator

The working principle of the Residue Regenerator Catalytic Unit (RCU) 15-R103/104 is to restore the catalyst's decreased activity after use in the hydrocarbon cracking process in the RCU reactor. During the cracking process, the catalyst becomes contaminated by coke deposits, a carbon layer formed as a reaction byproduct. This coke covers the active surface of the catalyst, reducing its ability to break down large hydrocarbon molecules. In the regenerator, the coke-saturated catalyst is cleaned through a combustion process using air. The coke is burned in a controlled manner to produce exhaust gases in the form of CO and CO_2. This allows the catalyst to be regenerated and returned to the reactor in an active state, allowing the reaction cycle to continue repeatedly. Another important function of the regenerator is as the main heat source in the Residue Catalytic Unit (RCU) system. The cracking process that occurs in the reactor is endothermic, meaning it requires a supply of heat energy for the reaction to proceed optimally. The regenerator, which is an exothermic unit, generates heat from the combustion process of the coke on the catalyst. This heat is not only used to raise the catalyst temperature but is also transported by the catalyst itself as it returns to the reactor. Therefore, the catalyst in the RCU system functions not only as an active substance but also as a heat carrier. The effectiveness of heat transfer from the regenerator to

p – ISSN: **1693 - 7945**
e – ISSN: **2622 - 1969**

the reactor is crucial for the success of the cracking reaction and for maintaining the overall operating temperature stability of the system (Pertamina EXOR-1, 1992).

Research Data

The operating condition data shown in Table 1 was used to calculate the performance of the 15-R - 103/104 regenerator, obtained from log sheet data in the Residue Catalytic Unit (RCU) at PT Kilang Pertamina International RU VI Balongan.

Table 1.

Operating Conditions of Regenerator 15-R-103/104

Variable	Unit	Value
Feed Capacity	Ton/hr	421.97
Temp.Upper	ºC	740.65
Temp.Lower	ºC	701.81
Press.Upper	Kg/Cm^3	1.61
Temp.MAB	ºC	182.85
Qwet	nm^3/hr	342.89
Temp.Reactor	ºC	527.02
Temp.Flue Gas	ºC	713.52
Flow Steam Cat.Cooler A/D	Ton/hr	70.72
Flow Steam Cat.Cooler B/C	Ton/hr	36.60

The regenerator performance calculation process uses international standard units. The Universal Petroleum Products (UOP) equation can be used to calculate the regenerator's mass and heat balances (Pertamina, EXOR-1, 1992). This formula will be equated to the units of actual operating conditions obtained from the field. In preparing the mass balance in this study, operational data for January 2025 was used, which was then divided into weekly data. The first week's data covers the 1st-7th, the second week's 8th-14th, the third week's 15th-21st, and the fourth week's 22nd-29th. The following are the mass and heat balance calculations for regenerator 15-103/104:

Table 2.

Regenerator Mass Balance

Week	Input		Output
	Coke (Kg/Hour)	Air (Kg/Hour)	Flue Gas (Kg/Hour)
1	41447.92	451779.37	493227.29
2	41560.51	453006.59	494567.10
3	41479.87	452127.69	493607.56
4	38555.67	420254.09	458809.76

p – ISSN: **1693 - 7945**
e – ISSN: **2622 - 1969**

Original Article

Table 3.
Regenerator Heat Balance

Week	Heat Balance					
	Input			Output		
	Coke (kJ/Kg)	ΔH Combustion (Corr.kJ/kg Coke)	ΔH_{Air} (kJ/Kg Coke)	Regen (Cat.kJ/Kg)	Cat.Cooler (kJ/Kg Coke)	Radiation loss (kJ/Kg Coke)
1	313.18	31677.16	6178.16	31626.11	5960.91	581.47
2	312.63	31677.03	6166.46	31628.76	5945.88	581.47
3	319.49	31678.49	6235.74	31170.29	6481.96	581.47
4	319.01	31678.34	6243.37	32071.32	5587.94	581.47
Amount	1264.31	126711.02	24823.73	126496.49	23976.69	2325.88
Total	152799.06			152799.06		

Amount	163043.97	1777167.74	1940211.71
Total	1940211.71		1940211.71

Table 2 summarizes the regenerator mass balance over a four-week operating period. As indicated in Table 2, the total mass input, comprising coke and combustion air, is equal to the total mass output in the form of flue gas, with both amounting to 1,940,211.71 kg/hour, thereby confirming satisfactory mass balance closure. The results show that combustion air represents the major contribution to the input stream, while the coke feed rate remains relatively constant during Weeks 1–3 and decreases in Week 4. A corresponding reduction in flue gas flow rate is observed in the same period, indicating a direct relationship between input fluctuations and output generation. Overall, the consistency between input and output streams suggests that the regenerator operates under near steady-state conditions with no significant mass losses (Sadeghbeigi, R, 2012). The balanced mass flow implies that the regenerator performs efficiently, ensuring that all input materials are completely (Mapwata, M., & Kanyinda, J. M., 2019).

In addition to the mass balance calculation, we also performed a heat balance to ensure that heat is utilized efficiently, to identify heat losses, and to maintain optimal operational performance. Converted and accounted for in the output stream. However, a slight decrease in the flow rate during the fourth week suggests a reduction in operating load, which may be attributed to variations in operating conditions such as temperature, air supply, or coke feed rate. Overall, the steady mass balance confirms the stability and reliability of the regenerator's performance during the monitoring period (Oloruntoba et al., 2022).

Table 3 presents the regenerator heat balance evaluated over a four-week operating period. As shown in Table 3, the total heat input, which includes the heat released from coke combustion and the sensible heat of combustion air, is equal to the total heat output, amounting to 152,799.06 kJ/kg coke, indicating satisfactory heat balance closure. The dominant contribution to the heat input arises from coke combustion, while the sensible heat of air provides a smaller but consistent contribution across all weeks. On the output side, the regenerated catalyst carries the largest portion of the released heat, followed by heat removal

p – ISSN: **1693 - 7945**
e – ISSN: **2622 - 1969**

Original Article

in the catalyst cooler, whereas radiation losses remain relatively constant throughout the observation period. These results indicate stable thermal performance of the regenerator and confirm efficient heat distribution within the system under near steady-state operating conditions (Selalame, T. W., et al., 2022). The main source of heat comes from coke combustion, while air plays an important role as a supporting medium for the oxidation reaction. Most of the coke is completely burned as the main source of heat input, and the energy (heat) balance has been quantitatively analyzed (F. Güleç et al., 2021).

Most of the generated heat is effectively utilized for catalyst regeneration and the heat loss is minimal (<2%), demonstrating a high level of system efficiency. As a result of the low heat loss shows that energy consumption plays a crucial role in process design for achieving cost-effective and sustainable production. Through heat integration, overall environmental performance can be improved by minimizing carbon emissions. Heat recovery serves as an effective approach to reduce energy requirements by reusing heat within the system and lowering both heating and cooling demands Minor fluctuations observed between weeks are caused by variations in operating conditions (such as air flow rate or catalyst loading), but these not significantly affect the overall stability of the system (A. T. Jarullah & N. A. Awad, 2019).

REGENERATOR EFFICIENCY

Based on Table 4 regenerator efficiency data in January 2025, the actual efficiency value varied each week. The lowest efficiency was recorded in week 3 at 56.13%, while the highest efficiency occurred in week 4 at 58.93%. The average efficiency value was 58%. In general, the optimal efficiency of the regenerator is in the range of 58-60% (Personal Interview with Field Supervisor, January 2025), where the coke combustion process occurs efficiently without causing afterburn or excessive coke buildup. The actual efficiency value that has reached optimal efficiency indicates that the catalyst regeneration process is running stably and efficiently. During January 2025, several equipment modifications and improvements were made that affected the performance of the regenerator. These modifications included the addition of molds to the propeller tube, improvements to the cyclone and orifice chamber, and updates to the MAB control system. These modifications contributed to the increase in efficiency, so that the results obtained did not deviate significantly from the optimal value. The regenerator efficiency is approximately 58%, indicating that the regenerator is still operating in good performance conditions. The overall thermal efficiency of the regenerator depends largely on the extent of coke combustion and the fraction of released heat recovered by the catalyst. (Oloruntoba et al., 2022).

Table 4.
Regenerator Efficiency

Week	ΔHComb.Corr (kJ/kg coke)	ΔH Regen (kJ/kg coke)	Efficiency (%)
1	31677.11	18207.02	57.98
2	31677.34	18589.70	58.07
3	31678.03	18415.71	56.13
4	31678.03	18335.40	58.93

p – ISSN: **1693 - 7945**
e – ISSN: **2622 - 1969**

The thermal performance of the regenerator over a four-week operational period is summarized in Table 4. The results indicate that while the corrected enthalpy of combustion (ΔHComb.Corr) remained remarkably stable, ranging from 31677.11 to 31678.03 kJ/kg coke, the energy recovered by the regenerator (ΔH Regen) exhibited minor weekly fluctuations. Consequently, the regenerator efficiency varied between a minimum of 56.13% in Week 3 and a maximum of 58.93% in Week 4. Despite the slight decline observed during the third week, the system maintained an average efficiency of approximately 57.78%. This relative stability suggests that the heat recovery process is consistent with the combustion input, although the variance in Week 4 indicates a peak in heat exchange optimization during that period (Basak, K.,et.al., 2018).

CORRELATION OF COKE YIELD TO REGENERATOR

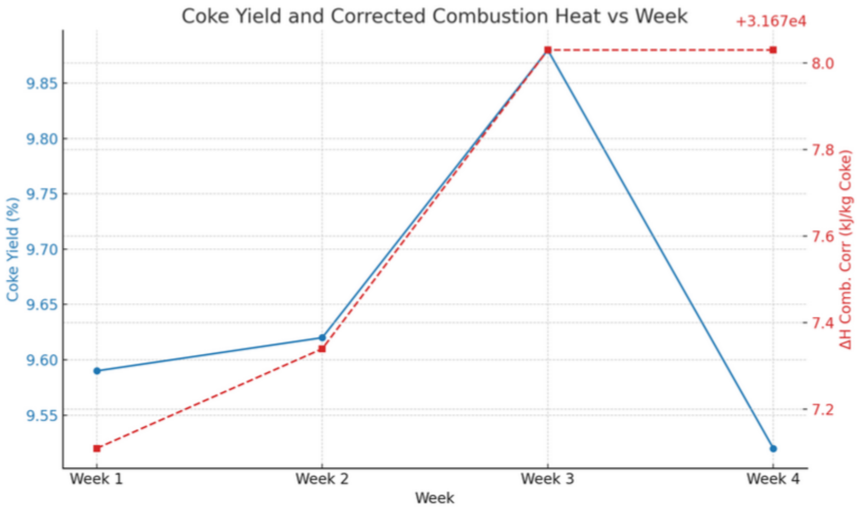
To determine the heat contribution from coke combustion to the energy balance in the regeneration process, the relationship between coke yield and ΔHComb.Corr Corrected for Hydrogen (ΔHComb.Corr) is analyzed using equations (15) and (22). This correlation is important because coke combustion is the main energy source in the regenerator system, and the value of ΔHComb.Corr reflects the total heat energy released after being corrected for the hydrogen content in the coke.

Table 5.
Correlation of coke yield with ΔHComb.Corr

Week	Coke Yield (%)	ΔHComb.Corr (kJ/Kg Coke)
1	9.59	31677.11
2	9.62	31677.34
3	9.88	31678.03
4	9.52	31678.03

The correlation between coke yield and the corrected enthalpy of combustion (ΔHComb.Corr) over the four-week observation period is presented in Table 5. The data reveals that the coke yield fluctuated within a narrow range, starting at 9.59% in Week 1 and reaching a peak of 9.88% in Week 3, before slightly decreasing to 9.52% by Week 4. Concurrently, the corrected enthalpy of combustion remained remarkably stable throughout the study, showing only marginal increases from 31677.11 kJ/kg coke to 31678.03 kJ/kg coke. This stability in enthalpy, despite the slight variations in coke yield, suggests that the energy content per unit of coke remains consistent regardless of the minor shifts in total production yield during the operational weeks (Sadeghbeigi, 2020; Gary et al., 2007).

Figure 4.
Correlation of coke yield with ΔHComb.Corr



Based on Figure 4, the relationship between coke yield and corrected heat of combustion for hydrogen (ΔHComb.Corr) during the first to fourth weeks shows a positive effect, especially in the early to mid-week. In the first to third weeks, coke yield increased from 9.59% to 9.88%, which was followed by an increase in the value of ΔHComb.Corr value from 31677.11 to 31678.03 kJ/kmol. This shows that the higher the coke yield formed, the greater the corrected heat of combustion energy due to the combustion of carbon in the coke, so that the relationship between the two is unidirectional or direct. However, in the fourth week, although the coke yield decreased to 9.52%, the ΔHComb.Corr remained constant at 31678.03 kJ/kmol. This phenomenon indicates that although coke yield is one of the factors affecting the ΔHComb.Corr value, there are other variables in the regenerator combustion system. Thus, coke yield influences ΔHComb.Corr, especially when there is an increase, but it is not the only determining factor. According to Yang et al. (2021**),** other factors affecting regenerator performance besides coke yield are the distribution of spent catalyst and the presence of horizontal baffles (crosser grids) in the regenerator. The even distribution of spent catalyst and the addition of baffle grids were shown to significantly increase the coke combustion efficiency**,** reduce afterburning at the freeboard**,** lower the carbon content in the regenerated catalyst**,** and stabilize the temperature and improve the residence time distribution of the catalyst in the dense bed.

4. Conclusion

The 15-R-103/104 regenerator in the Residue Catalytic Unit (RCU) uses a double-stage type that effectively functions to regenerate deactivated catalysts while providing the necessary heat for the catalytic cracking reaction in the reactor. Mass balance analysis shows that the flue gas output reaches 1940211.71 kg/hour, while the heat balance produces ΔH_Coke, ΔHCombustion.Corr, and ΔHAir values of 152799.06 kJ/kg coke, which are distributed to the regenerated catalyst, catalyst cooler, and radiation loss. The regenerator efficiency in January 2025 was recorded at 58%, within the optimal range of 58–60%, indicating that the device is operating well and its heat utilization is quite efficient. In addition, coke yield has a significant effect on regenerator performance, especially on ΔHCombustion.Corr, because increasing coke yield increases the heat energy generated from the combustion of carbon in the coke. Overall, this regenerator shows stable and efficient performance in supporting the catalytic cracking process.

p – ISSN: **1693 - 7945**
e – ISSN: **2622 - 1969**

Acknowledgments
The author would like to thank PT Kilang Pertamina Internasional Refinery Unit VI Balongan for the support and assistance provided in completing this study. The author hopes that PT Kilang Pertamina Internasional Refinery Unit VI Balongan will continue to develop and be successful in all its activities.

5. References

Basak, K., Abba, I. A., & Gupta, S. (2018). Thermal efficiency and energy management in fluid catalytic cracking units. *Applied Thermal Engineering*, 134, 455-468. https://doi.org/10.1016/j.applthermaleng.2018.01.112

Gary, J. H., Handwerk, G. E., & Kaiser, M. J. (2007). *Petroleum Refining: Technology and Economics* (5th ed.). CRC Press.

Güleç, F., Erdogan, A., Clough, P. T., & Lester, E. (2021). Investigation of the hydrodynamics in the regenerator of fluid catalytic cracking unit integrated by chemical looping combustion. *Fuel Processing Technology*, *223*, 106998.

Irawan, Rahmat Aldi, and Annasit Annasit. 2023. "Optimasi Regenerator 15R-103/104 Dengan Variasi Water Supply Pada Catalys Cooler System Di Residue Catalityc Cracker Unit PT. AAA." *Indonesian Journal of Energy and Mineral* 3(2): 97–115. doi:10.53026/ijoem/2023/3.2/1160.

Jarullah, A. T., & Awad, N. A. (2019). Energy consumption and heat recovery of an industrial fluidized catalytic cracking process based on cost savings. *Applied Petrochemical Research*, *9*(1), 1-11.

Mapwata, M., & Kanyinda, J. M. (2019). Modeling and Simulation of a Fluid Catalytic Cracking (FCC) Regenerator. *Journal of Chemical Engineering and Process Technology*, 10(2), 1-8. https://doi.org/10.4172/2157-7048.1000394

Nelza, N., Purba, D. C. S., & Savitri, A. N. (2023). Perhitungan Neraca Massa Pada Unit Screw Press di PT. XYZ. *JURNAL VOKASI TEKNIK*, *1*(01), 32-39.

Oloruntoba, A. (2022, March 15). Fluid Catalytic Cracking Catalyst Regeneration Intensification Technologies. In Encyclopedia. https://encyclopedia.pub/entry/20576

Perry, R.H., and Green. (1997). Perry's Chemical Engineer's Handbook. 7th edition. McGraw-Hill Book. New York

PERTAMINA EXOR-1. (1992). Pedoman Operasi: Unit 15 RCC Unit. JGC Corporation & Foster Wheeler (Indonesia) Limited.

Ramadhani, Y. (2019). Pengamatan Kondisi Operasi Reaktor dan Regenerator di RFCCU PT. Pertamina (Persero) RU III Plaju-Sungai Gerong. *ALKIMIA: Jurnal Ilmu Kimia dan Terapan*, *3*(1), 29-32.

Sadeghbeigi, R. (2012). *Fluid Catalytic Cracking Handbook: An Expert Guide to the Practical Operation, Design, and Optimization of FCC Units*. Butterworth-Heinemann.

Selalame, T. W., Patel, R., Mujtaba, I. M., & John, Y. M. (2022). *A review of modelling of the FCC unit—Part II: The regenerator*. **Energies, 15**(1), 388. https://doi.org/10.3390/en15010388

Singh, R., & Gbordzoe, E. (2017). Modeling FCC spent catalyst regeneration with computational fluid dynamics. *Powder Technology*, *316*, 560-568.

Smith, J.M., Van Ness H.C., About M. M., and Swihart M. T. (2018). Introduction to Chemical Engineering Thermodynamics. (8th ed). New York: McGraw-Hill Book Company Inc.

UOP. (1992). *UOP RCC Process Technology and Calculation*. PT Pertamina (Persero) RU VI Balongan

p – ISSN: **1693 - 7945**
e – ISSN: **2622 - 1969**

Original Article

Yang, Z., Zhang, Y., Liu, T., & Oloruntoba, A. (2021). MP-PIC simulation of the effects of spent catalyst distribution and horizontal baffle in an industrial FCC regenerator. Part II: Effects on regenerator performance. *Chemical Engineering Journal*, *421*, 129694.

Zahidin, A., & Rubianto, L. (2020). PERHITUNGAN NERACA MASSA, NERACA PANAS DAN EFISIENSI PADA ROTARY KILN UNIT KERJA RKC 3 PT SEMEN INDONESIA (PERSERO) Tbk. *DISTILAT: Jurnal Teknologi Separasi*, *6*(2), 309-315.