Design and Improvement of Atmospheric Distillation Unit in a Petroleum Refining Plant

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Introduction

Atmospheric Distillation Unit (ADU) is the first and most critical separation unit in petroleum refineries. It is responsible for separating crude oil into valuable fractions such as naphtha, kerosene, light gas oil, heavy gas oil, and atmospheric residue based on their boiling point differences. As the primary processing unit in a refinery, the performance of the ADU directly affects product yield, energy consumption, and overall refinery profitability. Therefore, improving the efficiency of the ADU is essential for maximizing hydrocarbon recovery and enhancing refinery performance.

Problem Statement

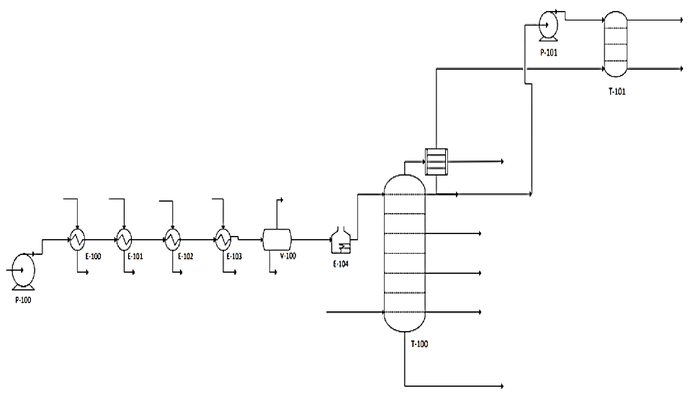
- **Hydrocarbon Losses:** Light hydrocarbons (C_1–C_5) escape with overhead gases and are routed to the flare system, losing valuable products and creating environmental impact.
- **High Energy Consumption:** Traditional designs rely heavily on furnace duty, imposing very high thermal requirements and elevated fuel consumption per barrel of crude processed.
- **Limited Heat Integration:** Inefficient recovery of heat from hot product side-draws means the preheat train under-performs, again increasing fired-heater load.

Objectives

- Design an improved Atmospheric Distillation Unit (ADU).
- Recover light hydrocarbons (C1–C5) using an absorber unit.
- Increase naphtha production.
- Reduce hydrocarbon losses to flare.
- Evaluate the technical and economic feasibility of the proposed design.

Design Methodology

Process Flow Diagram (PFD)



Equipment Design Specifications

1. Atmospheric Distillation Column (T-100):
- **Type:** Sieve Tray Column (2-Pass)
- **Diameter:** 5.7 m
- **Total Height:** 36 m
- **Actual Trays:** 32 Trays
- **Shell Thickness:** 20 mm
- **Tower Area:** 25.52 m²
- **Downcomer Residence Time:** 7.58 s

2. Heat Exchanger (E-103)
- **Type:** Fixed Tube sheet – TEMA AEL
- **Heat Duty:** 11,330,445 W
- **Heat Transfer Area:** 1405.735 m²
- **Number of Tubes:** 3668 tubes
- **Shell Diameter:** 1.65 m
- **Tube Length:** 6.10 m
- **Baffle Spacing:** 0.66 m

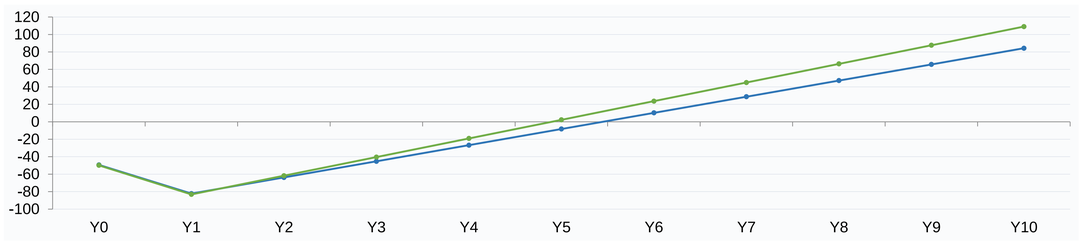
Results

Key Improvement: Absorber Integration

- **Naphtha Production:** increased from 86,800 kg/h to 93,568.72 kg/h.
- **Annual Increase:** about 53,609 tons/year of additional naphtha.
- **Extra Annual Profit:** approximately 4.02 million $/year.
- **Net Cash Flow Increase:** about 3.80 million $/year.

Economic Analysis

Parameter	Before Absorber	After Absorber
Fixed Capital Inv. (FCI)	$62.85M	**$63.60M**
Total Capital Inv. (TCI)	$82.28M	**$83.14M**
Annual Operating Cost	$93.07M/yr	**$93.29M/yr**
Annual Cash Flow	$18.50M/yr	**$21.35M/yr**
Payback Period	6.45 years	**5.89 years**
ROI	22.48%	**25.68%**
NPV (10 yr, 10% disc.)	$24.05M	**$39.16M**



Conclusions

- An improved Atmospheric Distillation Unit (ADU) was successfully designed
- Integration of the absorber unit increased naphtha recovery by 53,609 tons/year.
- The proposed design reduced hydrocarbon losses and improved overall process efficiency.
- The project achieved an additional annual profit of approximately 4.02 million USD/year.

Software Used

- **Aspen HYSYS:** Process simulation (steady-state, PRSV fluid package).
- **Microsoft Excel:** Material/energy balance calculations, economic analysis.
- **Visio / Word:** Documentation, HAZOP tables, report preparation

References