Operational Performance Diagnosis of a Continuous Ethylene Production Process

Author: Arul Nigam
Date: 14/02/2026

Objective

To analyse realistic plant operating data for a continuous chemical process, identify performance losses due to operational inefficiencies, and propose data-driven operating improvements.

This report is written from the perspective of a process engineer responsible for diagnosing underperformance in a running plant and recommending corrective actions based on operational data.

---

1. Introduction

The plant under study operates a continuous ethane cracking reactor producing ethylene via:

$$C_2H_6 \rightarrow C_2H_4 + H_2 \qquad (1)$$

The reaction is endothermic and therefore strongly temperature-dependent.

Over a six-month operating window, the plant exhibited:

- Variability in conversion
- Periodic heater duty spikes
- Fluctuating specific energy consumption
- Measurable downtime

The purpose of this analysis is not to describe the data, but to determine:

- What the true baseline performance is
- Where production is being lost
- Whether higher temperature operation is beneficial overall
- Which operational change delivers the greatest improvement per unit effort
- What trade-offs exist between throughput and energy consumption

---

2. Baseline Performance Definition

Baseline operation is defined as steady-state, non-fouled operation at 854 K.

Parameter	Value
Reactor Temperature	854 K
Conversion	0.53
Product Throughput	5.3 t/h
Specific Energy Consumption	0.0125 GJ/t
Heater Duty	17.5 ± 7.5 MW

This represents stable, clean operation without abnormal heater spikes.

Baseline production capacity:
5.3 t/h × 24 h/day = 127.2 t/day

This condition forms the benchmark against which inefficiencies are measured.

---

3. Analysis of Performance Losses

3.1 Downtime Loss

Total downtime observed: 9 days

Production loss:

5300 kg/h × 24 h/day × 9 days
= 1144.8 tonnes

Downtime is therefore the single largest contributor to lost production.

This loss occurs independent of temperature or fouling — meaning it is a structural reliability issue rather than a thermodynamic limitation.

3.2 Fouling Impact

Fouling index increases to 0.12–0.15 periodically, coinciding with heater duty spikes of 110–120 MW.

Under clean operation, heater duty averages 17.5 MW.

During fouling events:

- Conversion drops by ~0.02
- Throughput decreases by ~200 kg/h
- Events last ~2–3 days

Estimated total product lost due to fouling over six months:

≈ 108 tonnes

While fouling significantly increases energy consumption, its direct throughput impact is modest compared to downtime.

However, fouling introduces:

- Elevated energy cost
- Thermal stress
- Increased mechanical risk

Thus, its economic effect extends beyond lost tonnage.

3.3 Temperature vs Conversion

Conversion increases from approximately 0.48 to 0.60 across 820–920 K.

The positive correlation is consistent with endothermic kinetics.

However, scatter in the data indicates conversion variability of ±0.02 at a given temperature, likely due to:

- Feed variability
- Residence time fluctuation
- Minor heat transfer disturbances

Operating continuously at 920 K would increase conversion to ~0.58 and throughput by 500 kg/h.

Additional production over six months:

500 kg/h × 24 h/day × 29 days/month × 6 months
≈ 2088 tonnes

Technically, higher temperature improves throughput.

Economically, this improvement is constrained by increased heater duty and operating cost.

Without selling price or energy cost data, profitability cannot be conclusively quantified. However, observed SEC increases suggest diminishing economic return at higher temperatures.

3.4 Specific Energy Consumption (SEC)

Baseline SEC: 0.01–0.02 GJ/t

Fouling events increase SEC up to 0.07 GJ/t — approximately 3–5× baseline.

SEC spikes correlate directly with heater duty spikes, confirming that fouling is a major energy efficiency driver.

SEC monitoring therefore provides a reliable early-warning indicator for operational inefficiencies.

---

4. Trade-Off Between Energy and Throughput

The plant faces a clear trade-off:

Higher temperature → Higher conversion → Higher throughput
BUT
Higher heater duty → Higher SEC → Higher operating cost

Under current conditions:

- Baseline 854 K is economically stable
- 920 K increases throughput but likely reduces net margin

Therefore, temperature increase alone is not the optimal lever.

Energy efficiency improvement must precede aggressive temperature optimization.

---

5. Comparative Impact of Operational Changes

Strategy	Throughput Gain	Operational Effort	Overall Impact
Reduce Downtime	+1144.8 t	Moderate–High	Highest impact per effort
Eliminate Fouling	+108 t	Moderate	Improves energy efficiency
Operate at 920 K	+2088 t	Low (control change)	Economically uncertain

From a practical engineering standpoint:

Reducing downtime provides the greatest guaranteed improvement per unit effort.

---

6. Recommendations

1. Prioritize downtime reduction
    - Improve preventive maintenance planning
    - Analyze root causes of shutdowns
    - Improve reliability of critical systems
2. Improve heater efficiency before raising temperature
    - Investigate heat integration
    - Assess burner efficiency
    - Improve insulation

3. Implement proactive fouling management
    - Scheduled cleaning
    - Feed pretreatment
    - SEC-based monitoring triggers

---

7. Limitations and Assumptions

This analysis is subject to the following assumptions:

- Selling price of ethylene and energy cost were not provided; therefore, profitability is inferred qualitatively rather than calculated explicitly.
- Downtime duration was assumed constant regardless of temperature changes.
- Fouling frequency was assumed independent of operating temperature.
- Six months of data were assumed representative of long-term plant behaviour.
- No capital expenditure modelling was performed for equipment upgrades.

Further work should include:

- Detailed economic evaluation (NPV or margin analysis)
- Root cause analysis of downtime events
- Heat transfer modelling to quantify fouling resistance
- Sensitivity analysis of temperature vs profit

---

8. Conclusion

The plant is not primarily limited by thermodynamics — it is limited by operational inefficiencies.

Key findings:

- Downtime causes the largest production loss (1144.8 t).
- Fouling significantly increases energy consumption but has smaller throughput impact (108 t).
- Higher temperature improves conversion but introduces energy trade-offs.
- Baseline operation at 854 K represents a reasonable balance between throughput and efficiency.

The highest-impact improvement is reliability enhancement to reduce downtime.

This analysis demonstrates the ability to:

- Define baseline performance
- Quantify operational losses
- Evaluate trade-offs
- Prioritize corrective actions
- Communicate findings clearly in an engineering context