The Hydrogen Plant Problem

How Residual CUSUM Catches What Other Charts Miss. A real industrial case study: two hydrogen plants with a 17% efficiency gap, an invisible catalyst degradation problem, and the monitoring system that solved it.

Based on real events · Data fictitious for illustration · By Syd Stewart, StepChangeAnalysis.com · May 2026

Four findings

The problem

Two nominally identical hydrogen plants. Unit 2 consuming 17% more naphtha per tonne of hydrogen produced. Months of investigation — including a catalyst company consultant and the plant design engineers — produced no explanation. The signal was completely invisible on the shift control sheet.

The cause

A single paragraph in a technical reference book: catalyst activity can be permanently damaged if the steam-to-naphtha ratio falls below a critical threshold. Unit 2's catalyst had been degraded by a past steam failure and never recovered. Replacing the catalyst immediately returned consumption to Unit 1 levels.

Why standard charts miss it

A 17% naphtha overconsumption corresponds to a residual methane shift of just +0.49% — against a shift-to-shift noise of ±0.5%. Signal-to-noise ratio at the action threshold: 0.28. A Shewhart X-mR chart produces not a single signal across a full year containing a genuine, financially significant step change. CUSUM accumulates evidence; Shewhart charts discard it.

The solution

Residual CUSUM: strip out the production-rate effect by monitoring deviation from expected methane % at the current flowrate. CUSUM accumulates that tiny signal across weeks and months until it becomes unmistakable. Implemented with pen, paper, and one reading per shift — maintained by shift supervisors with no specialist software.

The three monitoring scenarios

SCENARIO 1 — SUDDEN CATALYST DAMAGE (STEAM FAILURE)

A steam failure drops the steam-to-naphtha ratio below the critical threshold. The damage occurs in hours. The CUSUM detects the step within 2–3 weeks. The boundary confidence is diagnostic of severity: 99.7% = severe damage; 95% only = marginal incident requiring close monitoring.

SCENARIO 2 — SLOW CATALYST DEGRADATION (SINTERING AND COKING)

Gradual deterioration over months and years — 0.00045% per reading, reaching 0.49% residual (17% naphtha overconsumption) over 3 years. Completely undetectable on any individual reading or rolling mean. The CUSUM accumulates the tiny signal continuously until it becomes unmistakable. Use 95% confidence for routine monitoring; 99.7% to confirm before committing to catalyst replacement.

SCENARIO 3 — THE REAL SCENARIO: SLOW DRIFT FOLLOWED BY DAMAGE EVENT

Slow sintering over years, then a steam failure accelerates the damage to a new worse level. The CUSUM correctly identifies 3 stages: healthy baseline, drift period, post-failure elevated level. The slope change at the steam failure is unmistakable — distinguishing the acute event from the underlying slow drift. 5000 loops required for consistent detection of marginal drift boundary.

The residual CUSUM method

Step 1 — Define the reference line:

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Expected % CH■ = 2.0 + (Flowrate% − 30) × (1.5 / 70)
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Step 2 — Calculate the residual for each shift reading:

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Residual = Actual % CH■ − Expected % CH■
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Step 3 — Apply CUSUM to the residual series. **Step 4** — Plot weekly averages colour-coded green/amber/red on the control room wall. Maintain a running CUSUM on a separate sheet. No specialist software required.

Key parameter guidance

Parameter	Recommended setting	Purpose
Confidence level — routine monitoring	95% (2-sigma)	Balanced speed vs certainty. Detects slow drift before it reaches crisis level.
Confidence level — irreversible action	99.7% (3-sigma)	Use when justifying a full catalyst replacement or plant shutdown.
Turn Length (TL)	40–60 (2–3 weeks of readings)	Filters spurious stage boundaries from shift-to-shift noise.
Bootstrap loops	5000 minimum	Required for stable detection of marginal drift boundaries (SNR = 0.28).
Monitoring frequency	3 readings per shift (shift start)	Provides 1,095 annual observations for robust CUSUM accumulation.

Download the data files

Four CSV files are available at stepchangeanalysis.com/hydrogen-plant-cusum.html. Upload with Y = Residual_pct to reproduce all charts shown in the article.

File	Scenario	Rows
`hp-baseline.csv`	Healthy catalyst baseline — Jan 2020 to Jan 2021	1,095
`hp-stepchange.csv`	Sudden steam failure at Day 180	1,095
`hp-slowdrift.csv`	Slow catalyst degradation over 3 years	3,285
`hp-combined.csv`	Slow drift followed by steam failure	3,285

References

• Page E.S., "Continuous Inspection Schemes." Biometrika, 1954;41(1–2):100–115.

• Taylor W.A., "Change-Point Analysis: A Powerful New Tool For Detecting Changes." 2000. variation.com

• Efron B. & Tibshirani R.J., An Introduction to the Bootstrap. Chapman & Hall, 1993.

• Johnson Matthey / Haldor Topsøe — Nickel steam reforming catalyst technical literature.

Read the full article and download CSV files
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All four scenario CSV files are available for download directly from the article. Upload to StepChangeAnalysis.com to reproduce every chart shown, and apply the method to your own process data.