Petronas
Reformer paper
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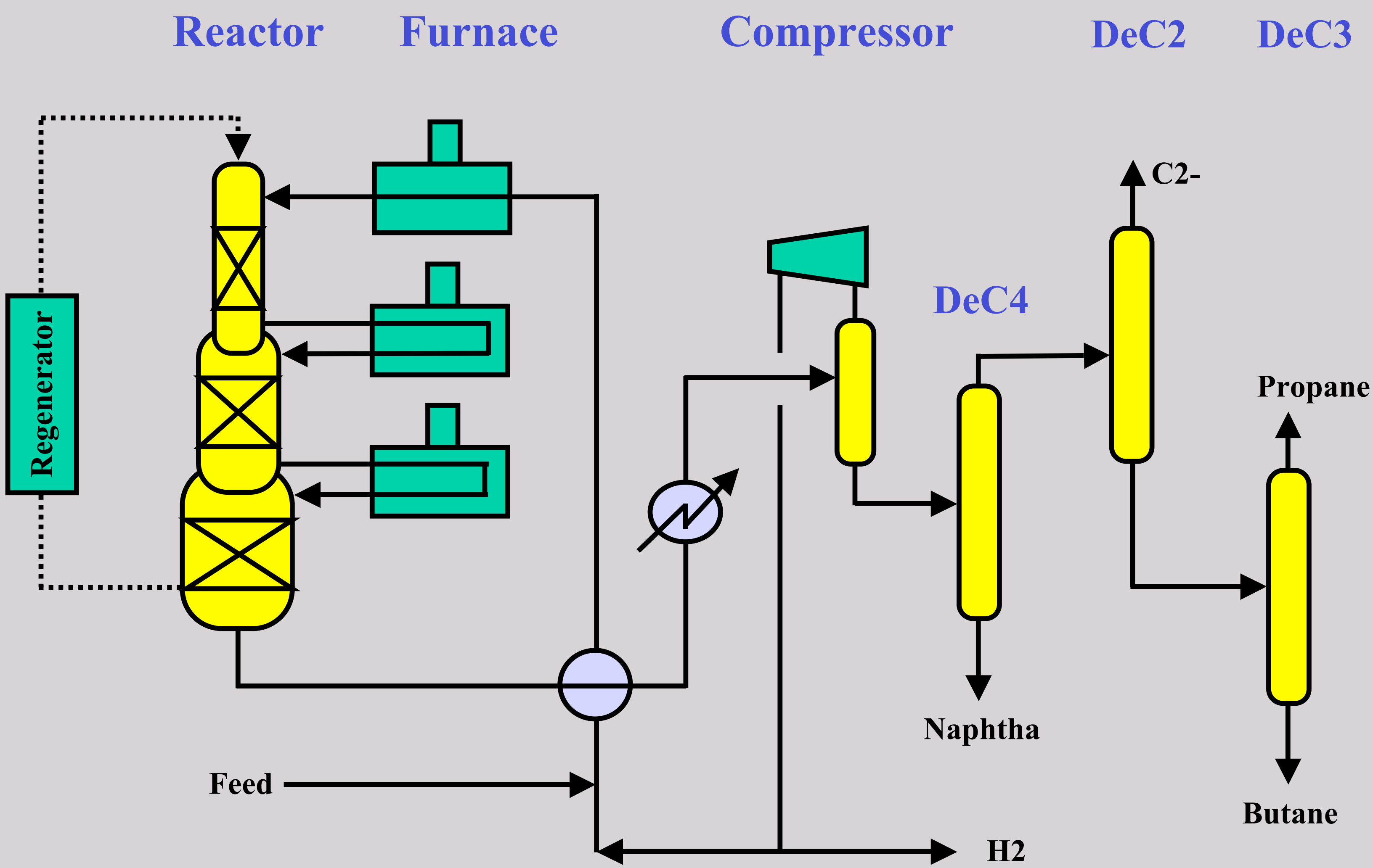
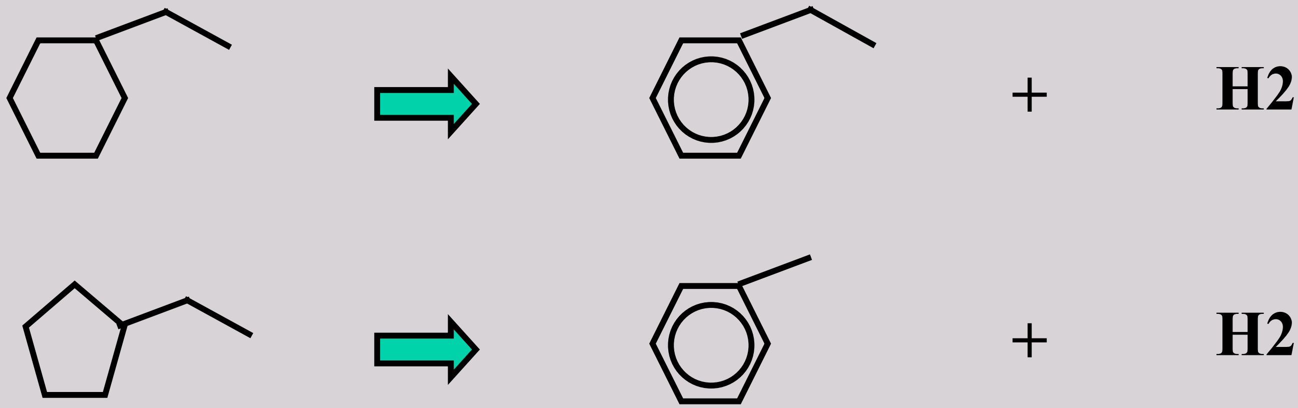
Simplified reformer configuration



Aromatization



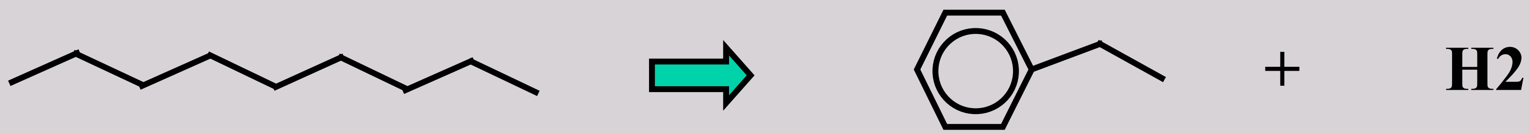
Main reaction, nearly 100% conversion

The naphtha product is very aromatic

➡ high octane

The reformer is a large producer of hydrogen

Dehydrocyclization



Difficult reaction, promoted by low pressure

NC6 reaction not very effective in semi-regenerative units, ~20% conversion

CCR units (low P) ~50% conversion

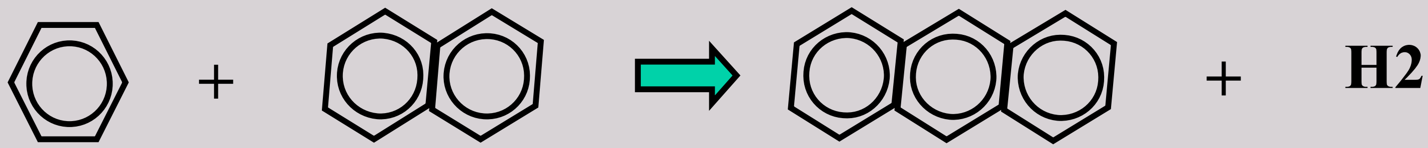
NC7 converts better, 40 - 80+% conversion

NC8 better yet, 70 - 95+% conversion

Cracking side reaction

Un-dehydrocyclized, low octane components, are cracked

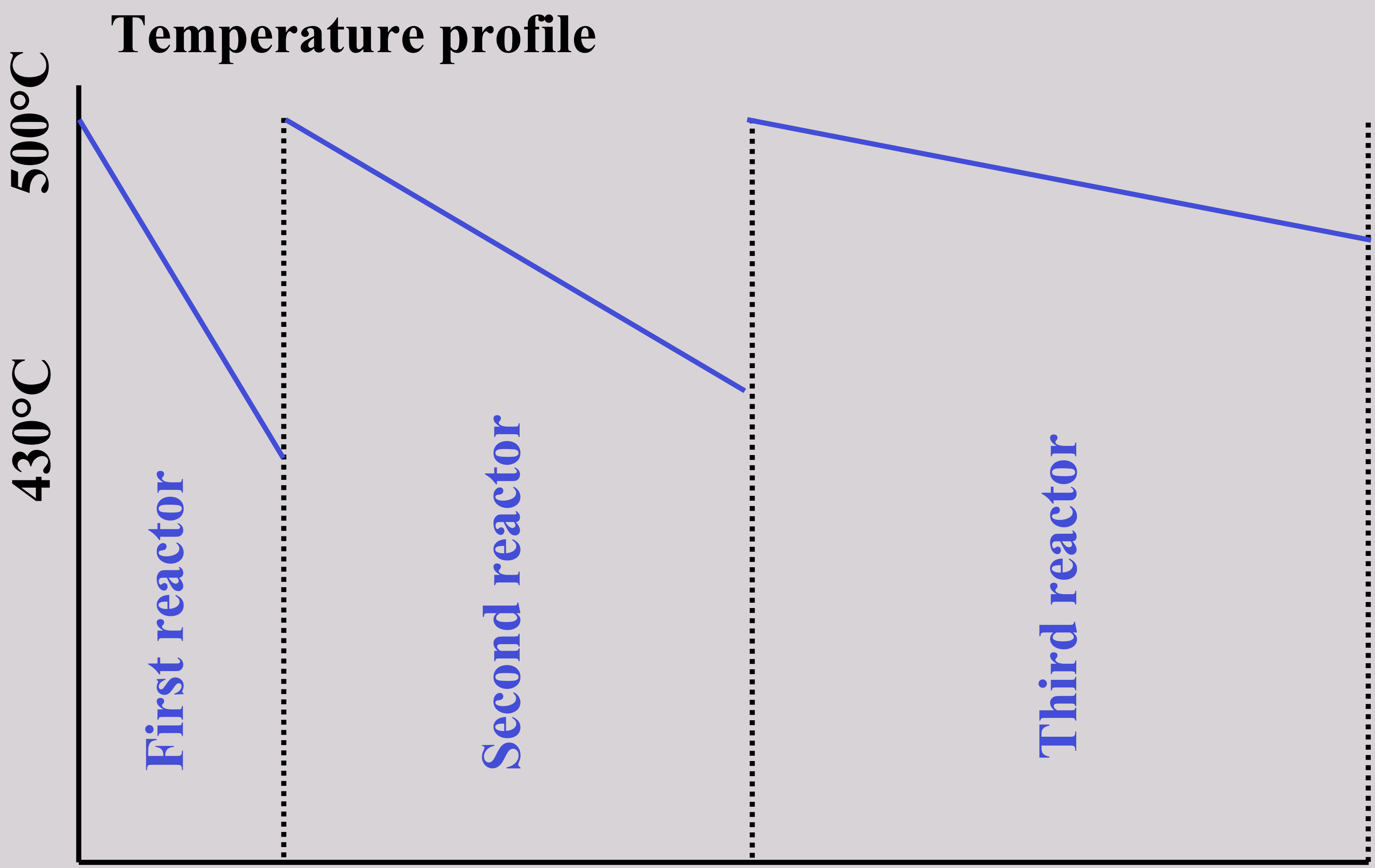
Aromatics condensation ➡ Coke



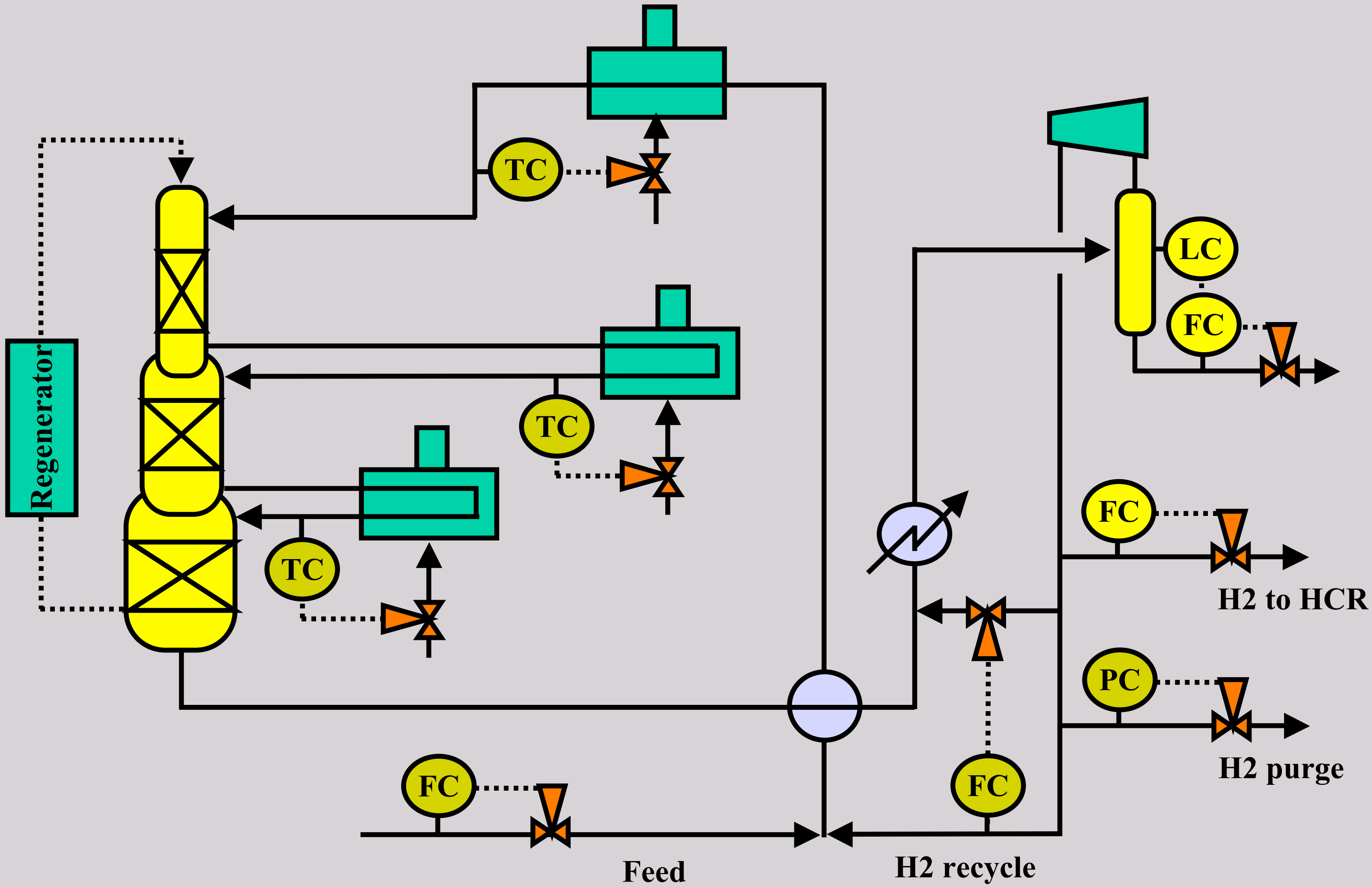
Coke gradually accumulates on the catalyst surface

Working with high ratio H2 circulation to tilt the balance against coking

The reaction is endothermic



Main reactor controls



Reactor control

- **Control octane by changing WAIT**
  - **(weighted average reactor inlet temperature)**
  - **Keep all inlets the same, except as needed to alleviate constraints**
- **Control catalyst coking rate by manipulating hydrogen recycle ratio**
  - **Keep the coking rate within the regenerator capacity**
- **Regenerator reliability problem**
  - **Frequent regenerator trips may dictate temporary throughput cuts**

Manipulated variables

- **Reformer feed flow**
  – **Maximize feed subject to reactor and NHT throughput constraints.**
- **Reactor inlet temperatures**
  – **Handles for controlling reactor severity**
- **Recycle compressor suction valve**
  – **Handle for controlling the hydrogen recycle ratio**

Control variables – 1

- **Octane number calculation**
  - **Octane inference is the main CV for controlling the reformate octane**
- **Coke on catalyst laydown calculation**
  - **Coke laydown inference may become an active constraint upon regenerator trip**
- **Reactor inlet H2/HC mole ratio**
  - **Normally the H2/HC ratio is set at 1.5, though it should be increase if there is a coke laydown problem**

Control variables – 2

- **Throughput hydraulic constraints**
- **Recycle compressor constraints**
- **Reactor temperature profile CVs**
  - **Profile is to be respected subject to furnace constraints**
- **Furnace constrain CVs**
- **Certain NHT constraints**
  - **In rare situations the upstream naphtha hydrotreater may impose throughput limits on the reformer**

Control variables – 3

- **Hydrogen purge**
  - **Half way through the project economic drives changed. The reformer is now operated solely for the purpose of supplying hydrogen**
  - **We added a hydrogen purge constraint to keep the purge low**

This control relies on knowledge of octane and rate of coking

- Octane measurement (or in our case inference) is a must
  - Keep catalyst coking rate within regenerator capacity
  - Steady octane operation improves yield
- Coking rate inference is good to have
  - Otherwise we must operate at a conservative hydrogen ratio
  - Affects unit efficiency and capacity

What affects octane?

- **Feed boiling point**
  - Conversion increases with molecule size
- **PNA (paraffin – naphthene – aromatic)**
  - Aromatics ride through, they already have high octane
  - Naphthenes convert at 100% to high octane aromatics, but that conversion requires high reactor temperature
- **H2 recycle**
  - Partial pressure effect is minor

What affects coke make?

- **WAIT**
  - **Coke make increases with reactor temperature, especially in the last reactor**
- **H2 recycle**
  - **Partial pressure effect is major**

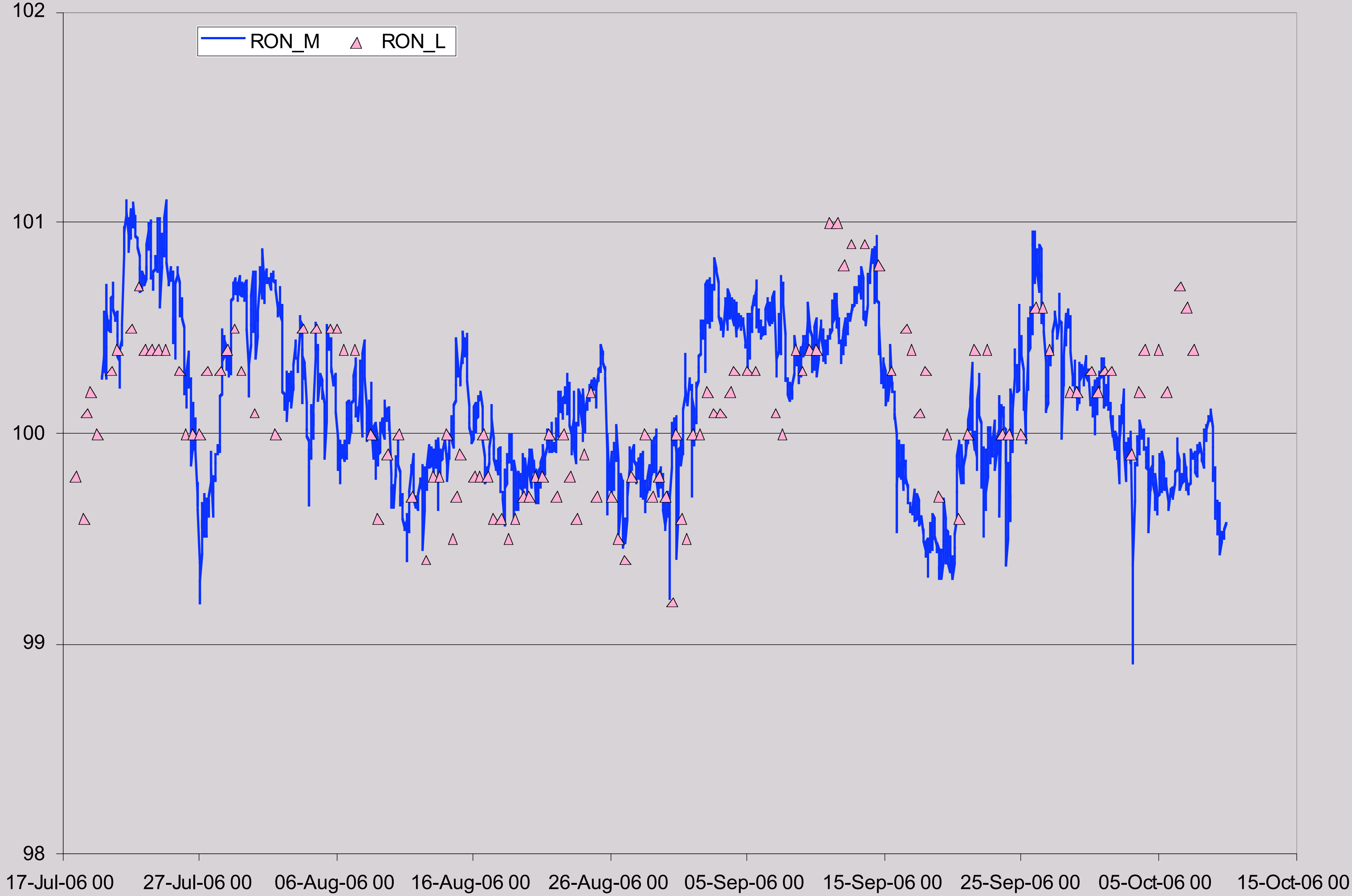
Inference of feed boiling point

- **Ideally feed boiling point should be inferred on the upstream crude unit**
  - **Not possible at Melaka because there are several feed sources**
  - **Inference is based on debutanizer bottom conditions, corrected for C4 and C5 separation**

Inference of feed PNA

- **Ideally feed PNA is inferred from**
  - **Feed boiling range**
  - **Reactor conditions**
  - **Feed density**
- **But the feed density analyzer is not installed yet, and the model assumes a constant PNA distribution**
- **Quality of octane inference is acceptable but not great**

Octane trend at Melaka



Petrocontrol

Octane trend at another location, incorporating density measurement

Coke deposit trend [Kg/Hr]

% coke on catalyst

How this application makes money?

- **At "normal" economic situation**
  - **Maximize feed at constant octane, considering reactor and regenerator constraints**
- **At current depressed economics**
  - **Minimize feed at constant octane to provide the needed H2 supply while keeping H2 purge at minimum**
- **A feed reduction of 5% was observed**

Conclusions

- **Reforming is a sensitive high temperature catalytic process with many constraints**
- **APC of the reformer reactor requires reasonable inferences of**
  - **Reformate octane number**
  - **Catalyst coke deposit rate**
- **APC engineers must adjust applications for the economics of the day**