Johnson Matthey
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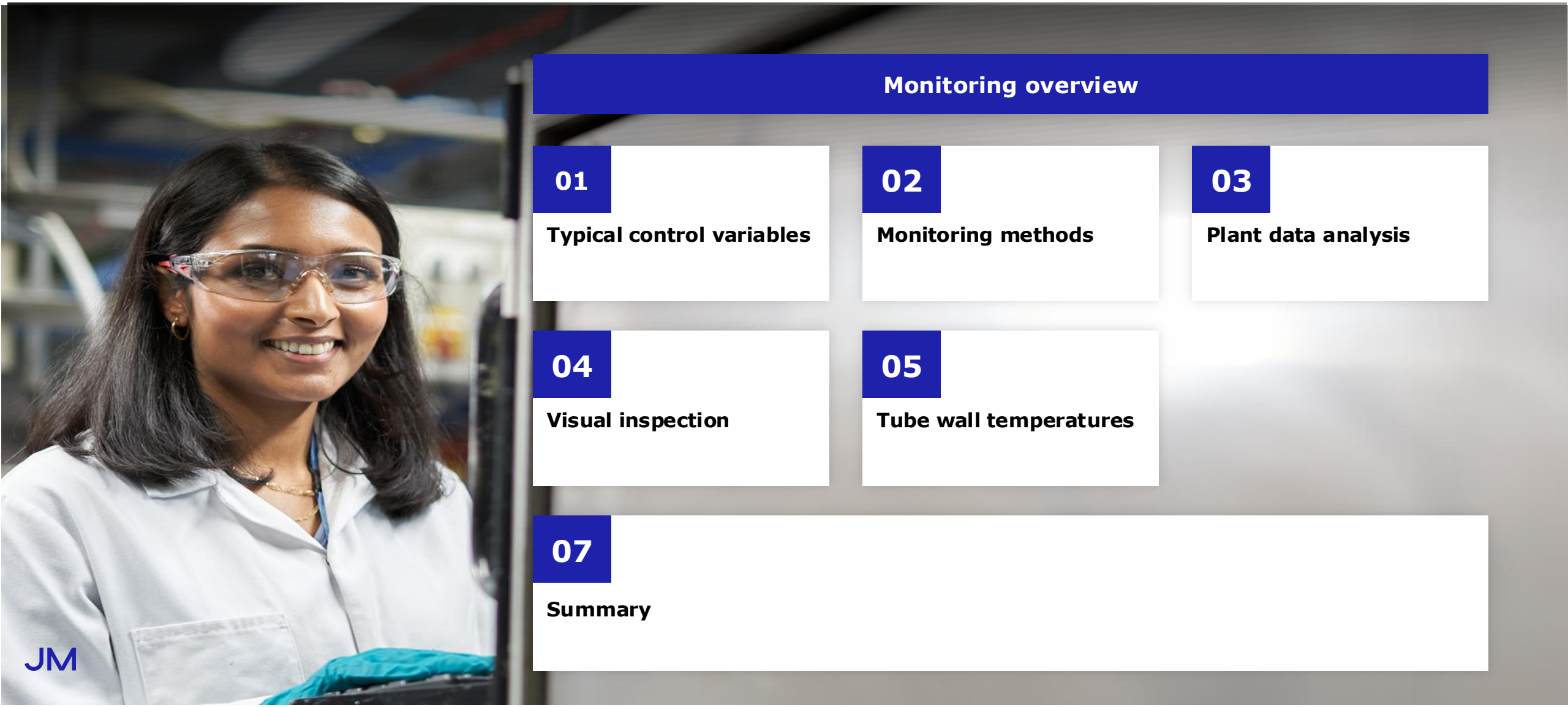
Americas hydrogen and syngas technical training seminar

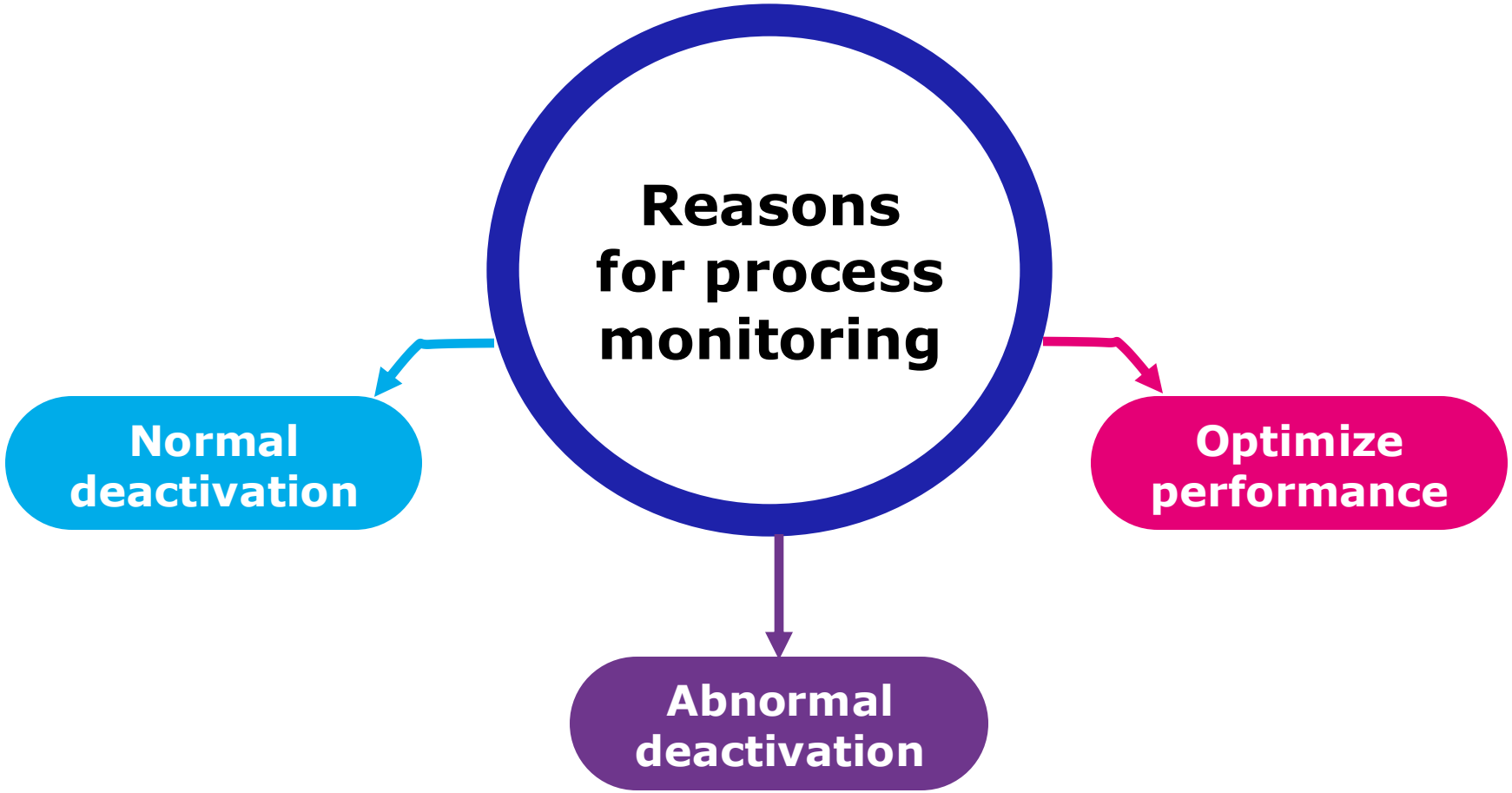
Monitoring of steam reformers during operation

Olawunmi Odunola



Monitoring overview

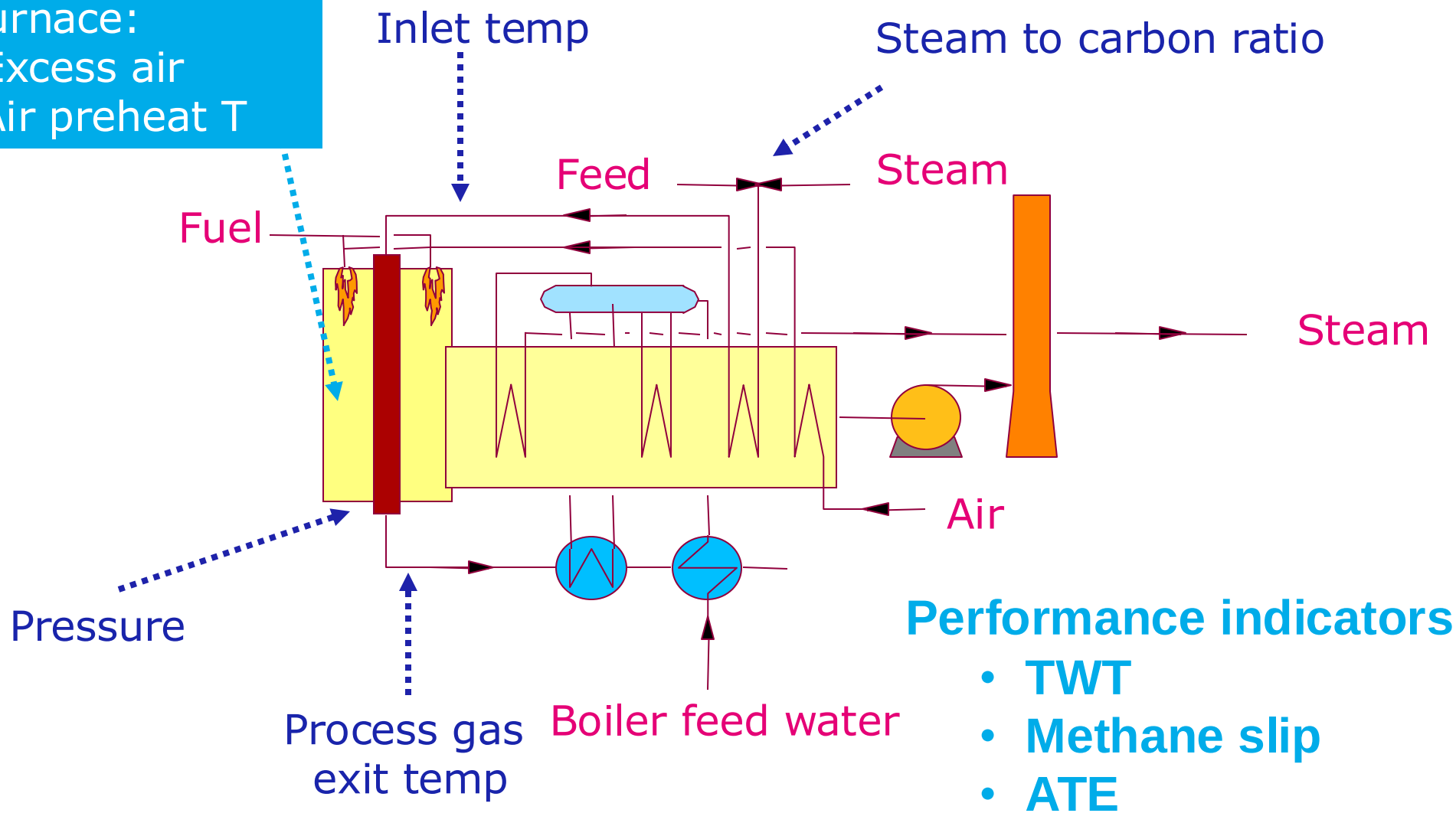
Introduction



Typical control variables

$$F_{[CH_4]} = \frac{F_{[CO]}\ F_{[H_2]}^{3}\ P_{tot}^{2}}{K_{ms}\ F_{[H_2O]}}$$

Furnace:
-Excess air
-Air preheat T

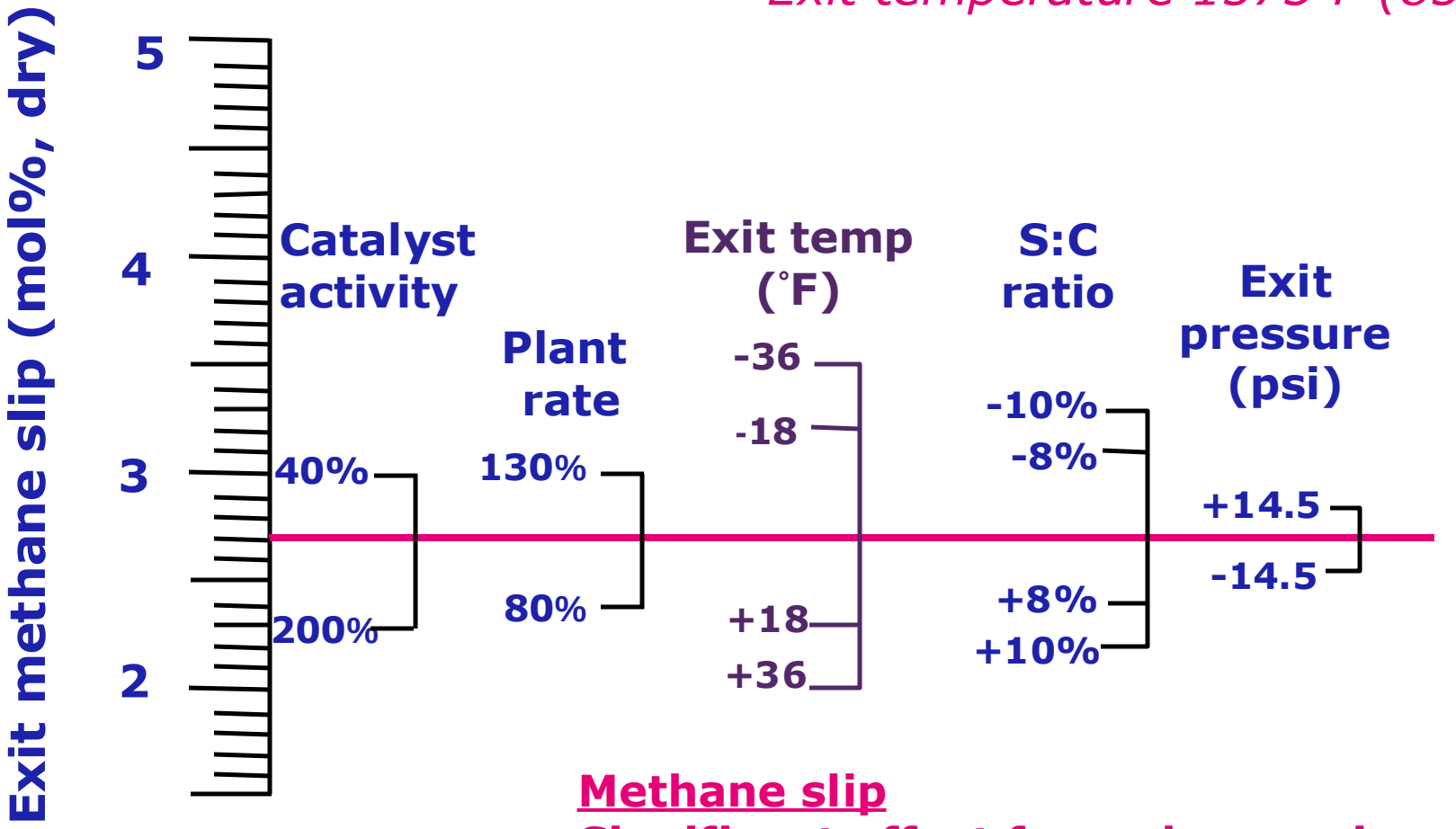


Performance indicators:

- **TWT**
- **Methane slip**
- **ATE**

Top fired – Methane slip

Exit temperature 1573°F (856°C)



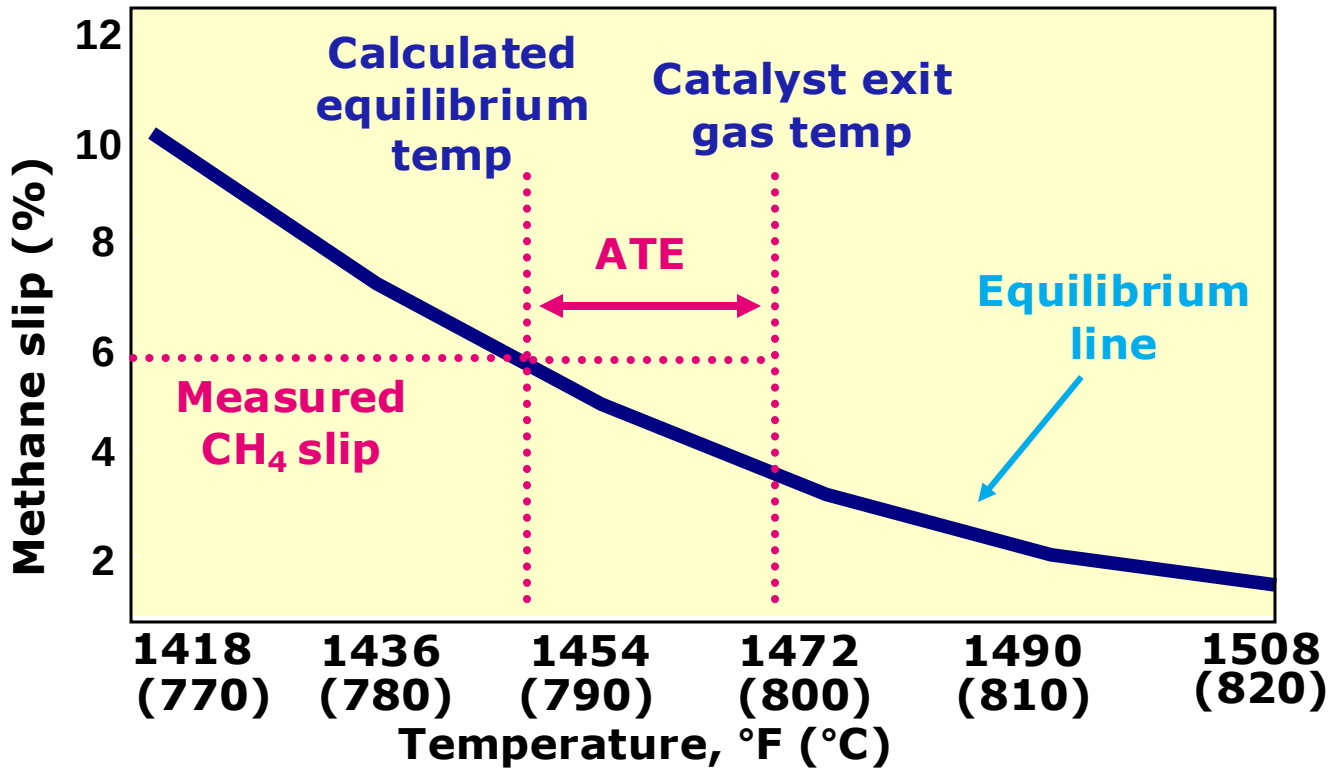
Methane slip

Significant effect from changes in:

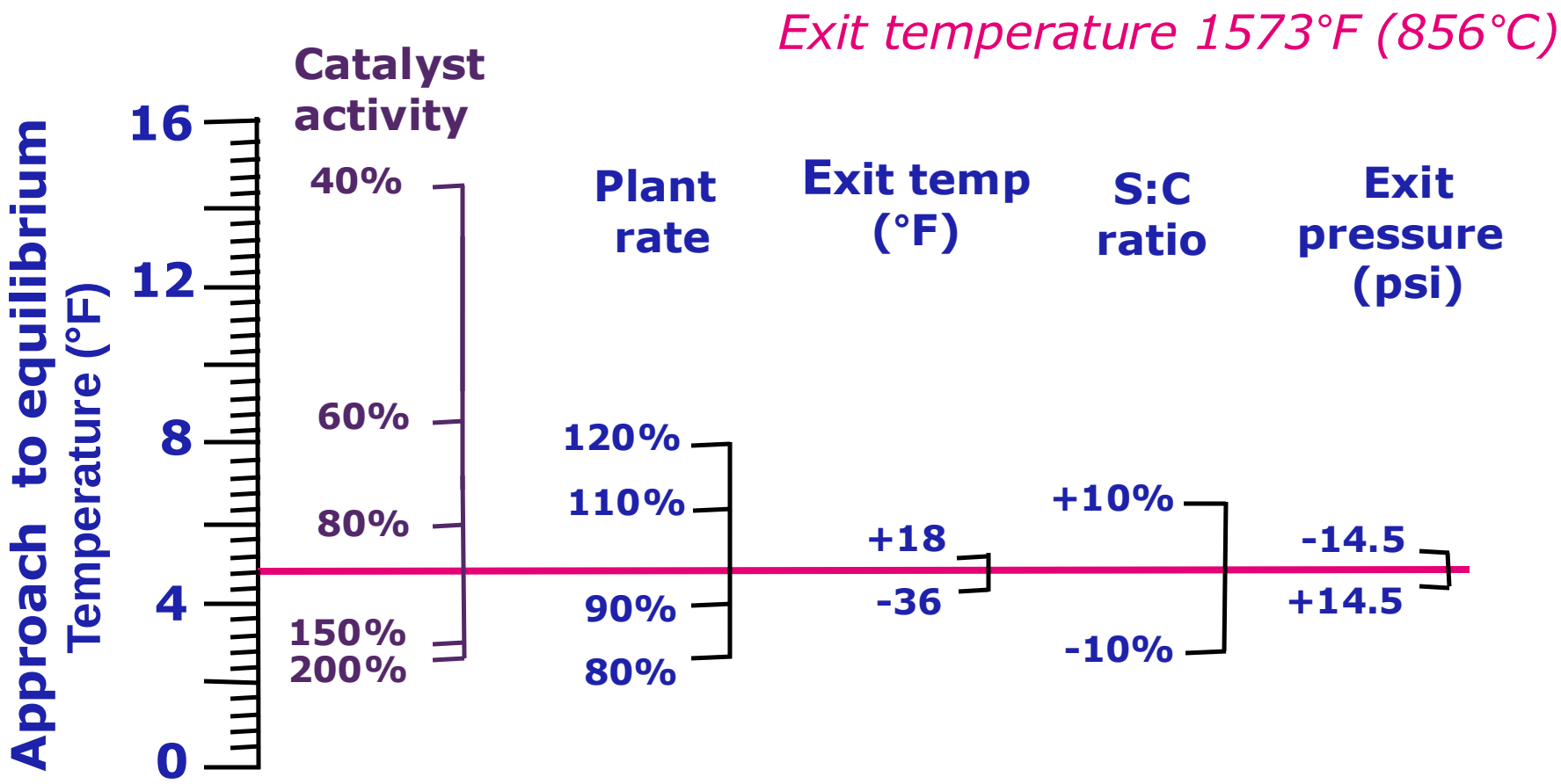
- **Exit temperature**
- **Steam to carbon ratio**

Performance indicator - ATE

- Approach to equilibrium (ATE)
  - Alternative measure for monitoring performance of catalyst
  - Increasing ATE indicates decreasing activity (at constant conditions)



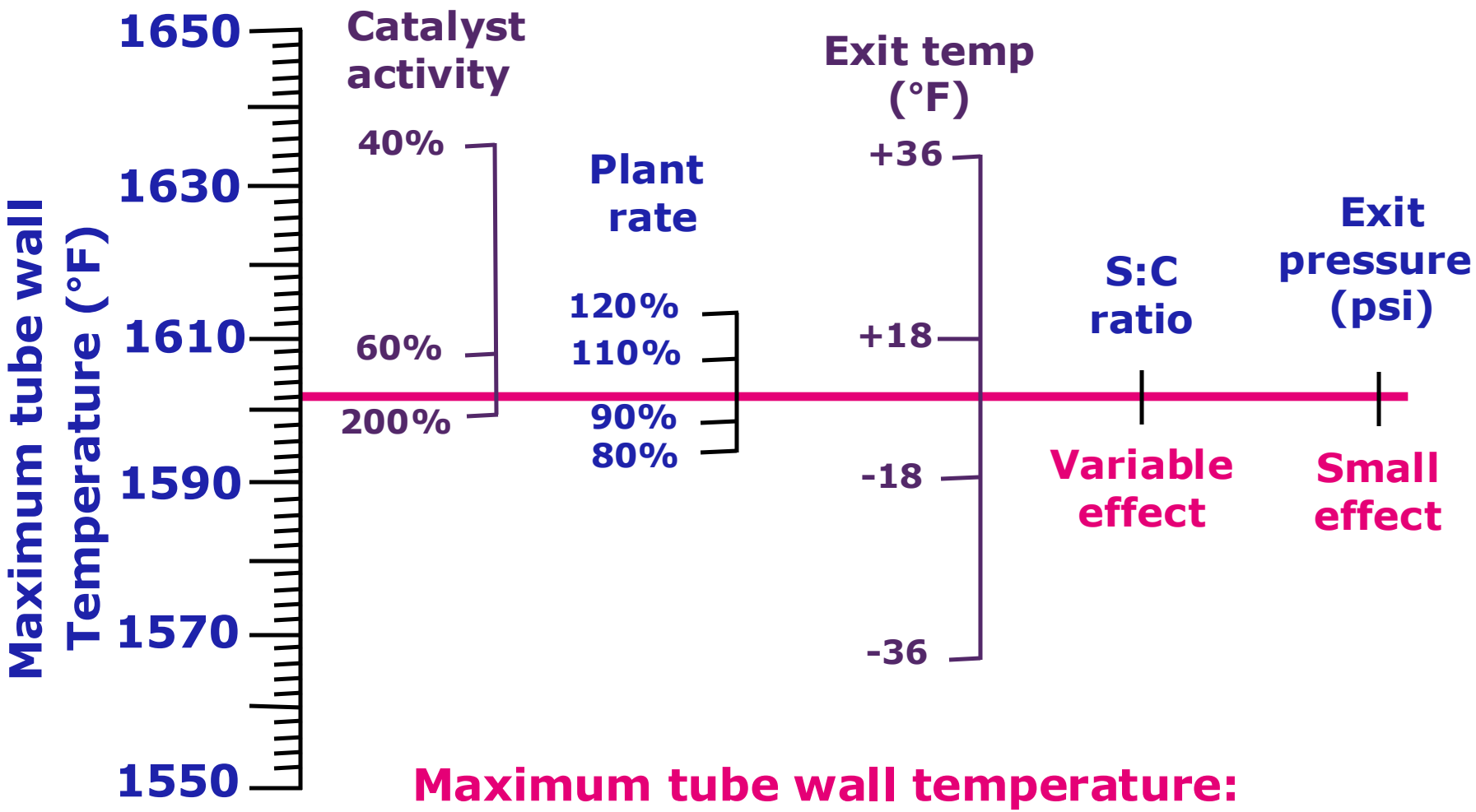
Top fired – ATE



Approach to equilibrium:
- Catalyst activity has relatively more impact

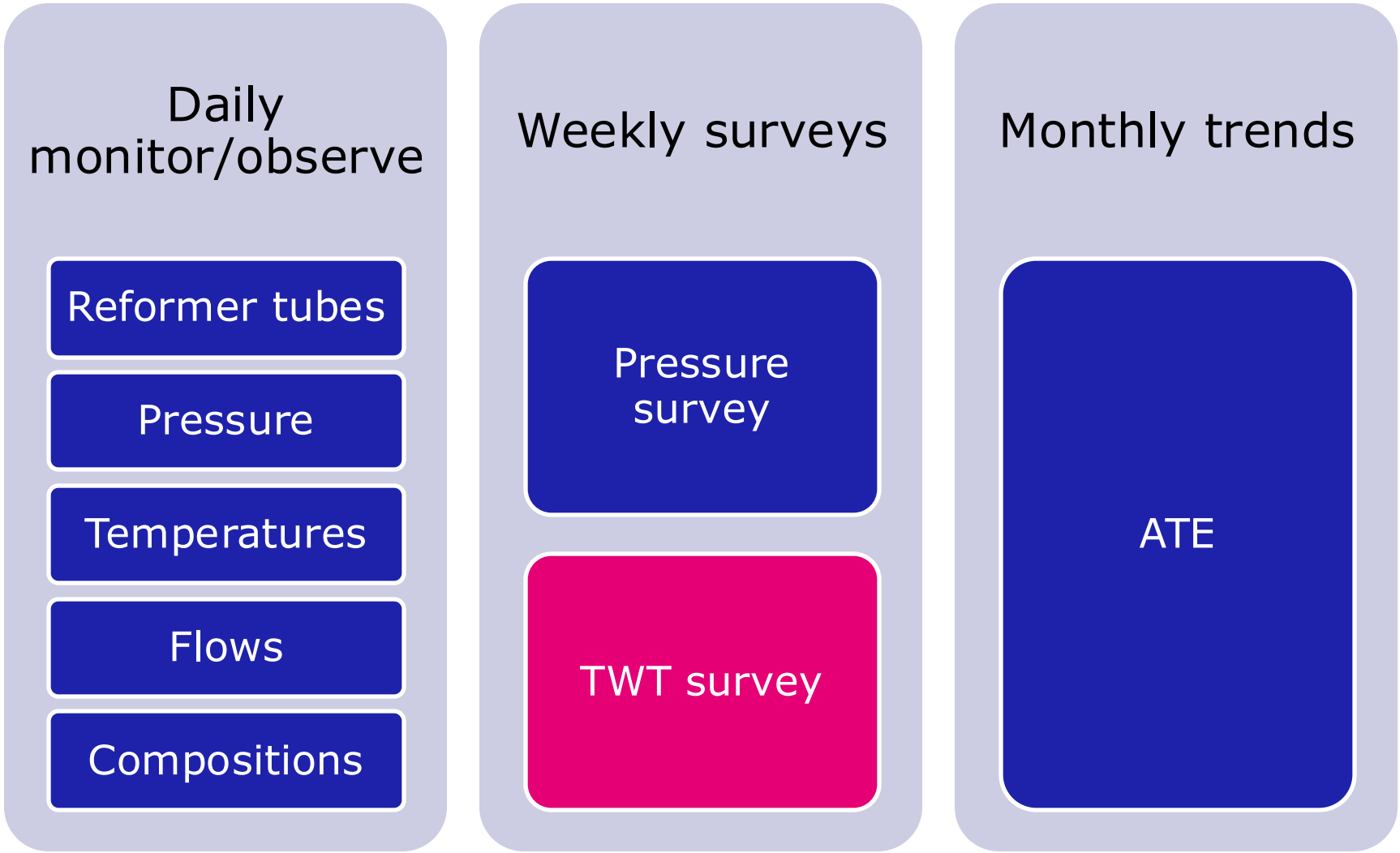
Top fired – Tube wall temperature

Exit Temperature 1573°F (856°C)



Maximum tube wall temperature:
At constant exit temperature, catalyst activity can have relatively more impact

Plant monitoring



Plant data analysis

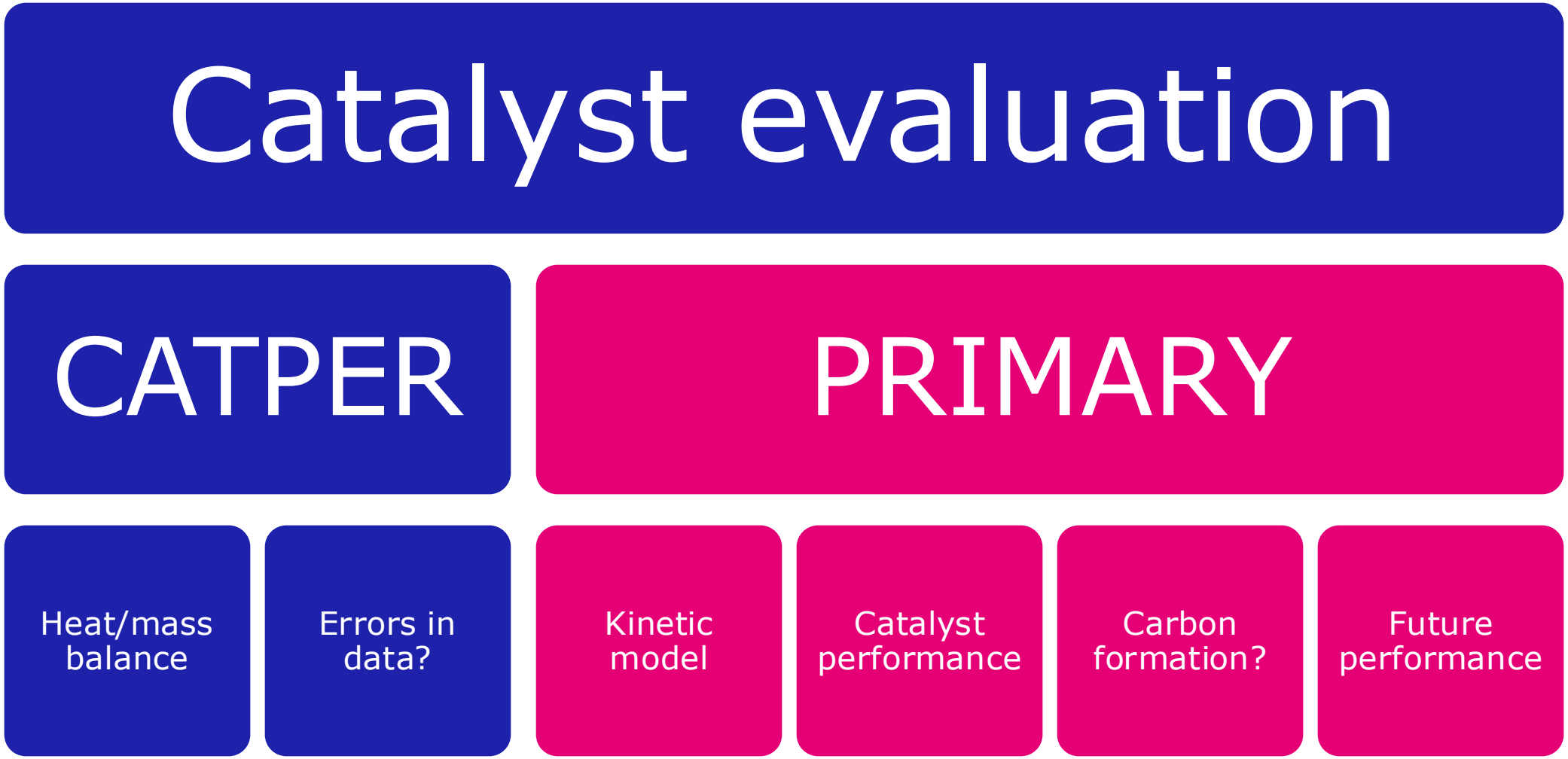
Plant

- Trend data to find discrepancies
- Create material and energy balance of plant
- Check against design specifications

Catalyst vendor

- Detailed modeling
  - Material and energy balance
  - Kinetic models

Plant data analysis – Modeling



Plant data - Common issues

Exit gas composition

- Additional CO shift reaction occurs if sample not cooled quickly
- Sample collection for analysis must be taken in the same time frame as the process data

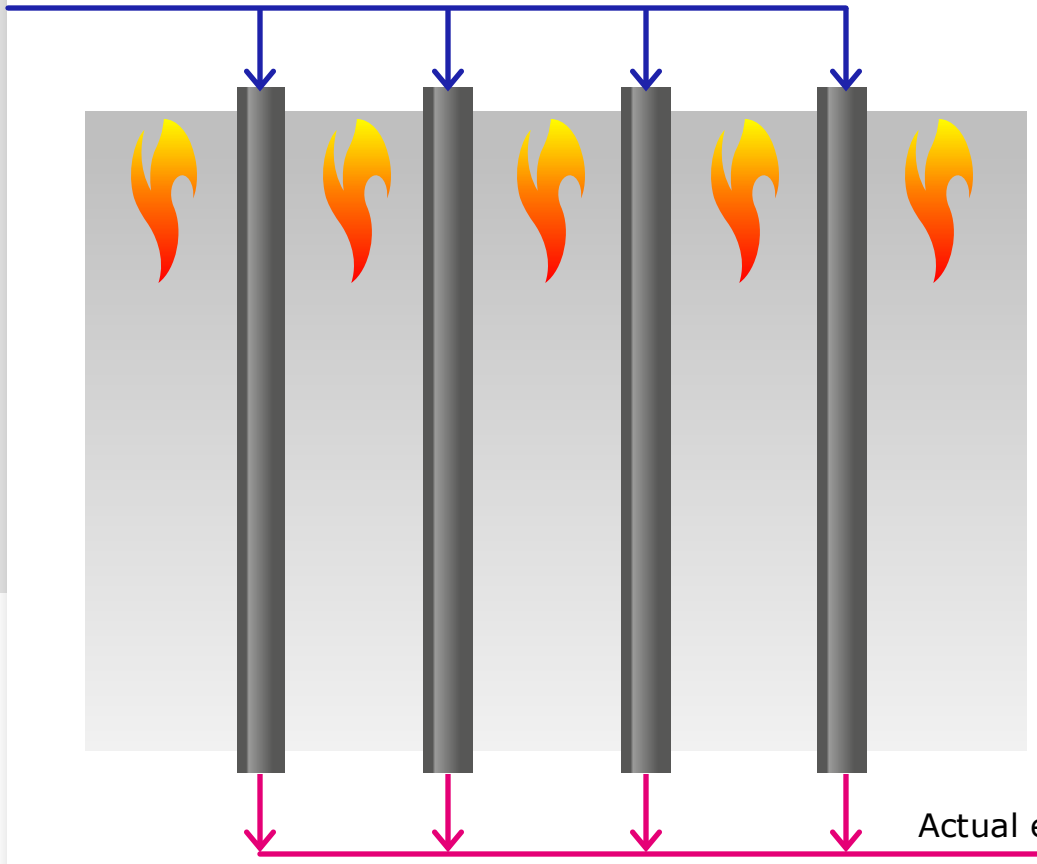
Flow measurements

- Variations in feed composition or multiple feed streams
- Steam meter is often less accurate causing S:C ratio error

Exit temperature

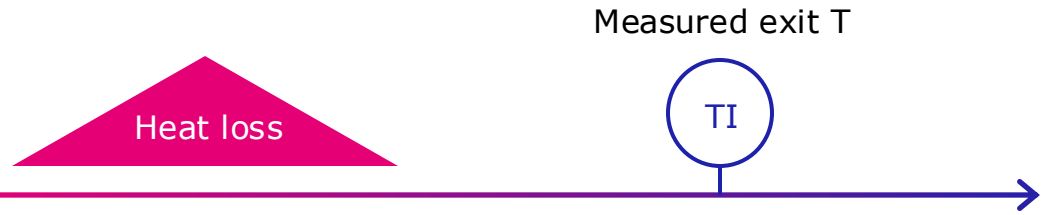
- Heat/mass balance requires actual catalyst exit temperature
- Plant temperature measurement often located at inlet to waste heat boiler
- Heat loss will affect actual vs. expected outlet gas composition

Plant temperature measurements at low rates



Actual temperature at reformer exit cannot be reliably measured

Rate	Heat leak, MW	Measured exit T, °F (°C)	Actual exit T, °F (°C)
100%	2	1602 (872)	1629 (887)
50%	2	1602 (872)	**1656 (902)**

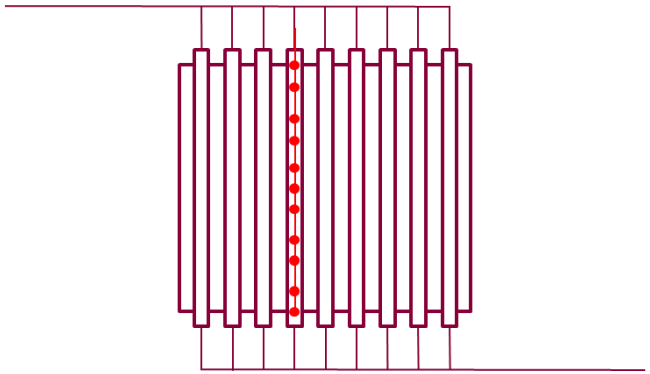


CatTracker®: Process gas measurement

CatTracker® is a multipoint temperature probe installed inside the reformer tube

Provides actual gas process temperature:

- Process monitoring
  - Faster reacting temperature readings
- Carbon protection
- Start-up trip system
- Model validation

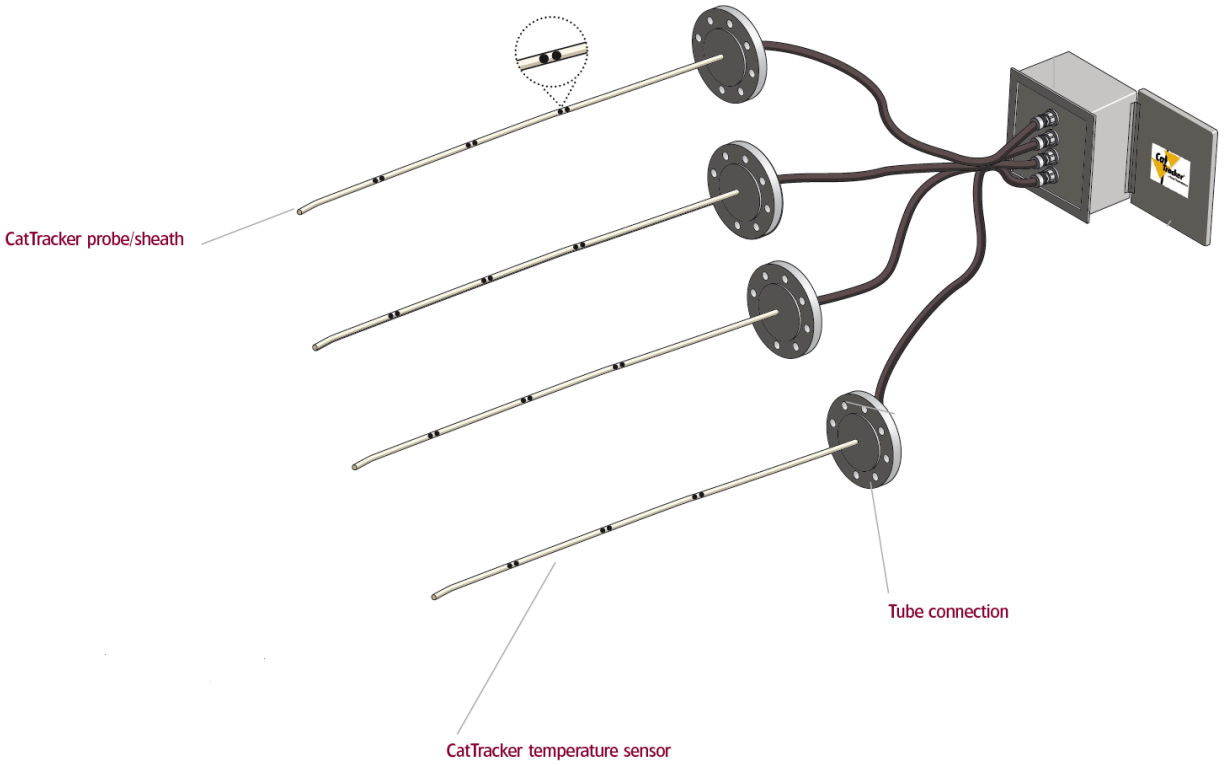


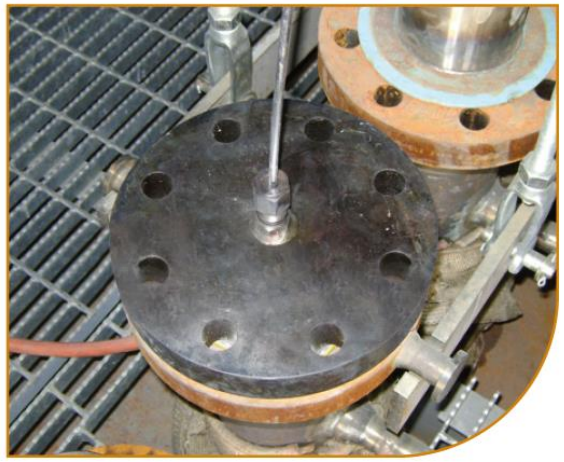
Johnson Matthey successfully installed **CatTracker®** in:

- Top fired
- Side fired

JM

Reformer CatTracker® probes: DCS connectivity



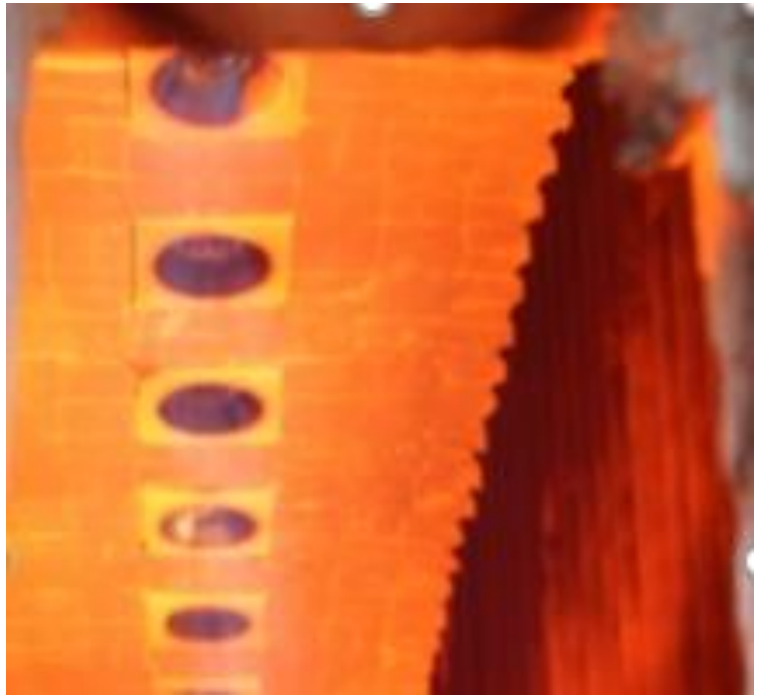


CatTracker installed in a reformer tube

US Patent # 9056295 and 9623391

Visual inspection of the reformer

Tube appearance



Refractory condition

External hot-spots

Flame characteristics

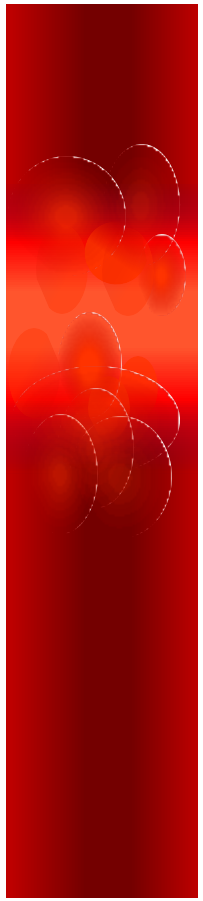
Tube appearance

The visual appearance of the tubes can be an early indication of problems and can be used to determine the root cause before the performance of the unit is significantly impacted.

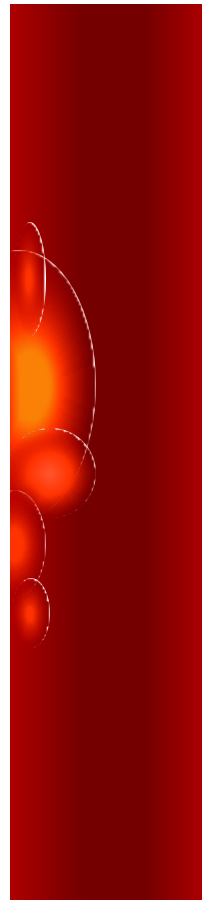
Hot bands – normally caused by catalyst poisoning or carbon formation.

Hot spots – suggest a localised mechanism, such as flame impingement or catalyst bridging.

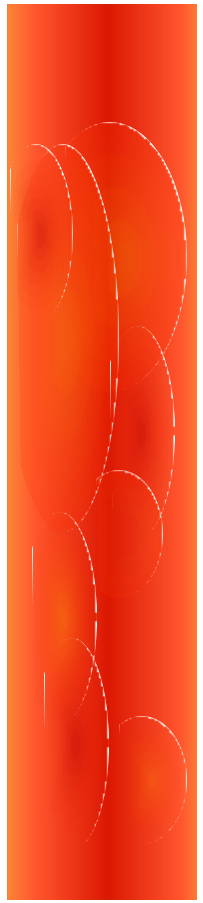
Hot tubes – an indication of a restriction of gas flow through the tube.



Hot bands



Hot spots



Hot tubes

Importance of TWT measurement

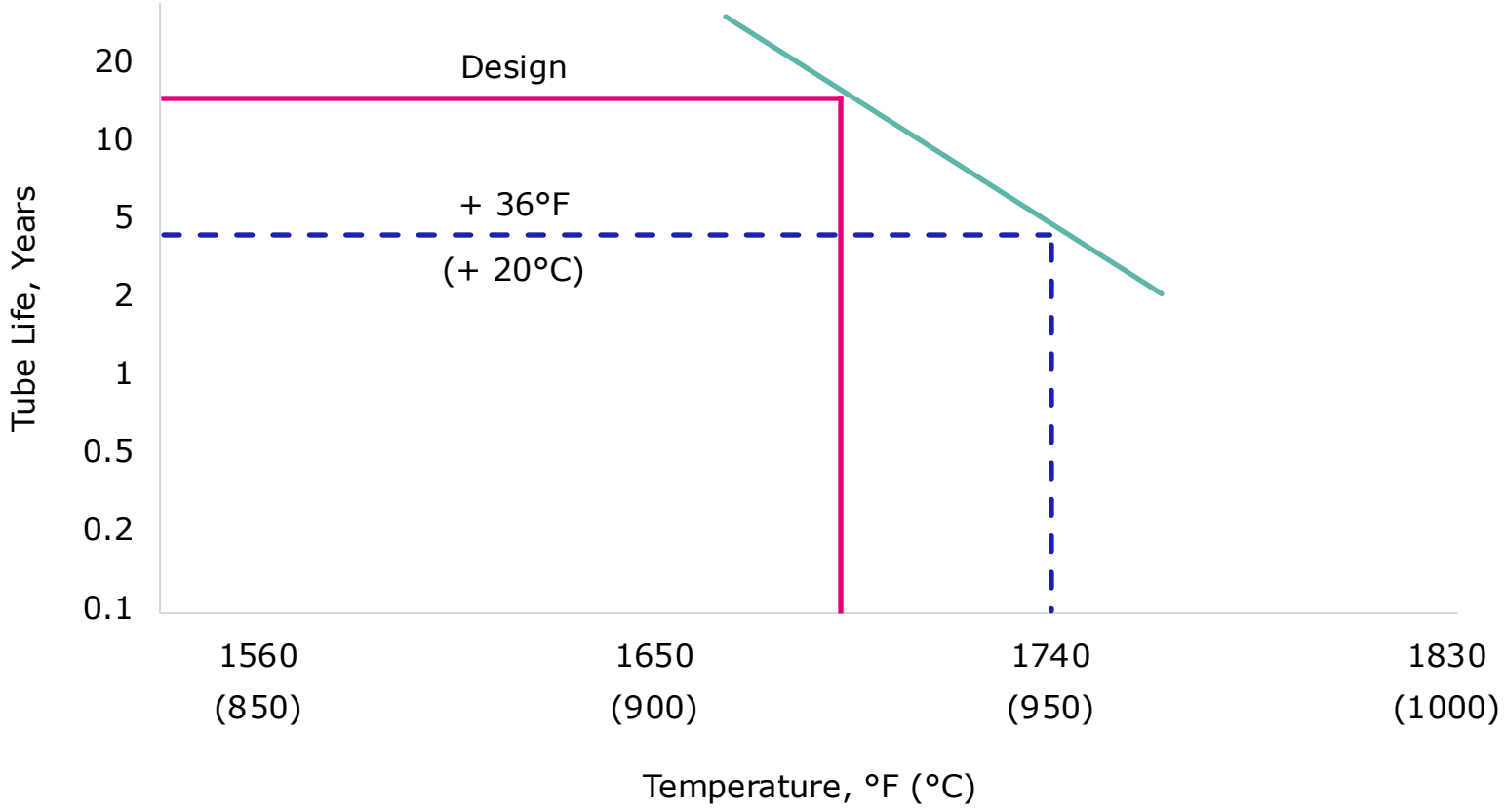
Tube repair/replacement is expensive – want to maximize life

Tube life is a function of time at temperature (for a given pressure)

Accurate measurement is vital

If measured **high**, might artificially **limit plant rate**

If measured **low**, tube life **shorter than expected**



*Note design temperature is at design pressure (normal operation is generally below design pressure)

What is a reformer survey?

Accurate assessment of reformer performance

1

Measurement and correction of tube temperatures

2

Inspection of reformer

3

Plant data collection and reconciliation

CATPER

4

Detailed simulation

PRIMARY

5

JM reformer surveys

Optical pyrometer measurements

Gold cup TWT measurements

Thermal imager measurements of radiant box

LAND / AMETEK®

TWT Measurement – Non-contact

Pyrometers

Laser
- Not good for curved tubes

IR Optical
- 0.9 µm or 3.9 µm
- Only one datapoint

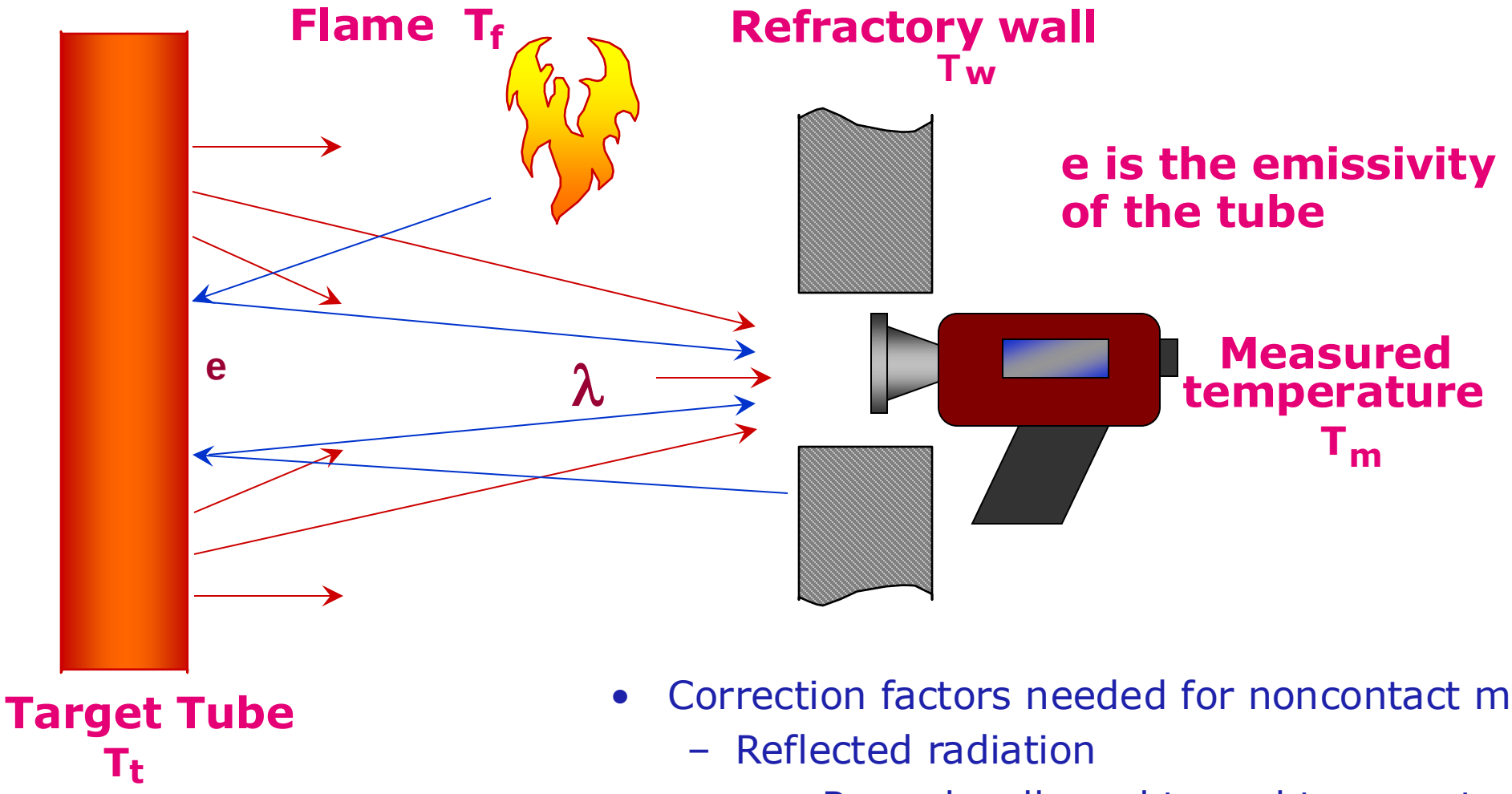
Cameras

IR Cameras
- 5-10 µm – Results in error
- Restricted view

Reformer Imager
- 1 µm
- Fisheye Lens
- Records to computer

Emissivity correction required

Effect of reflected radiation



- Correction factors needed for noncontact methods
  - Reflected radiation
    - Record walls and tunnel temperatures
    - Calculate actual tube temperature

Potential reformer issues

Poisoning 1

Carbon formation 2

Tube failure and replacement 3

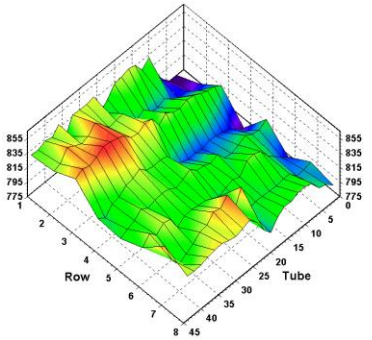
Fluegas maldistribution 4

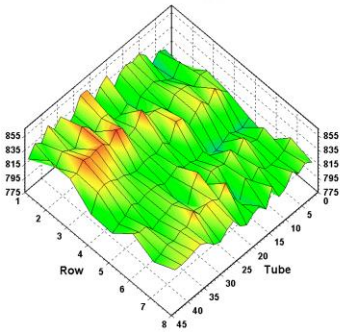
Burner problems 5

Refractory and tunnel damage 6

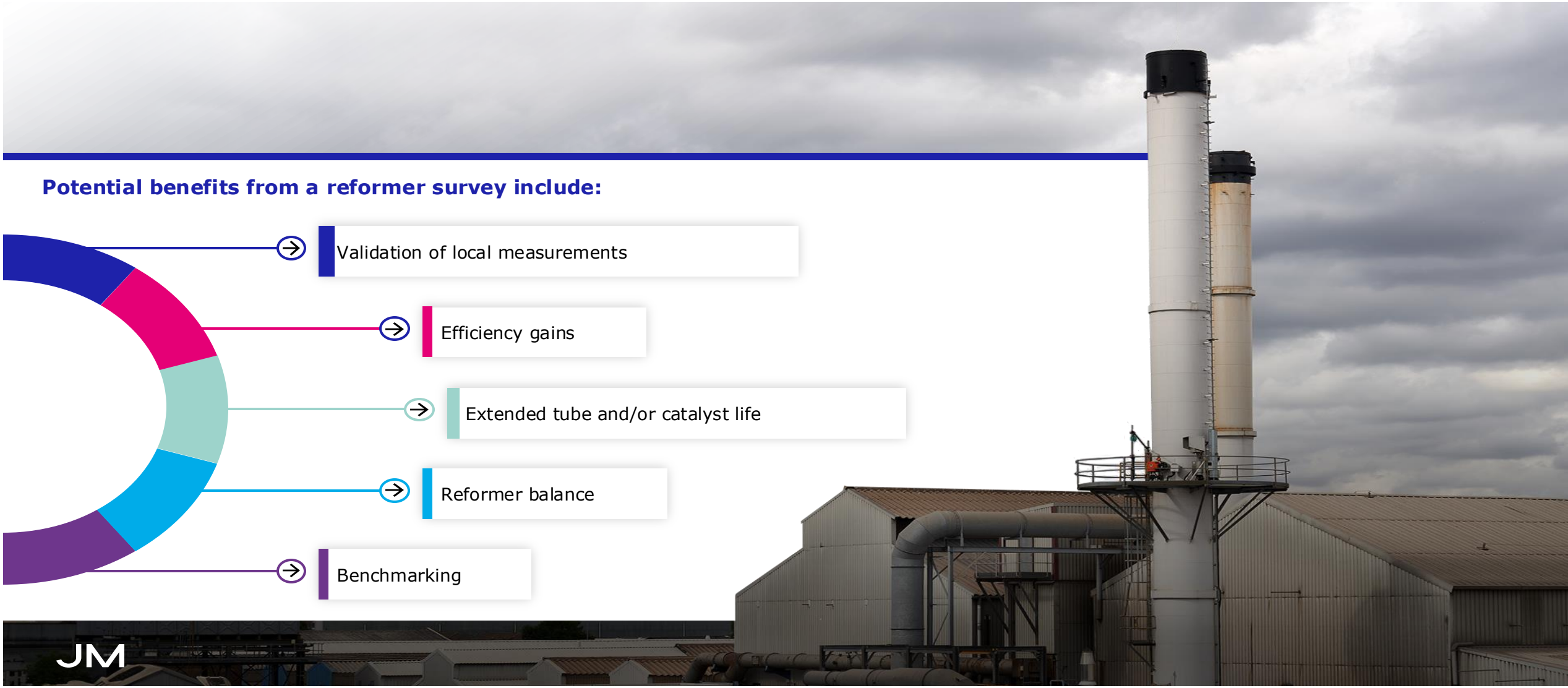
Combustion air maldistribution 7

Corrosion 8





Reformer survey benefits

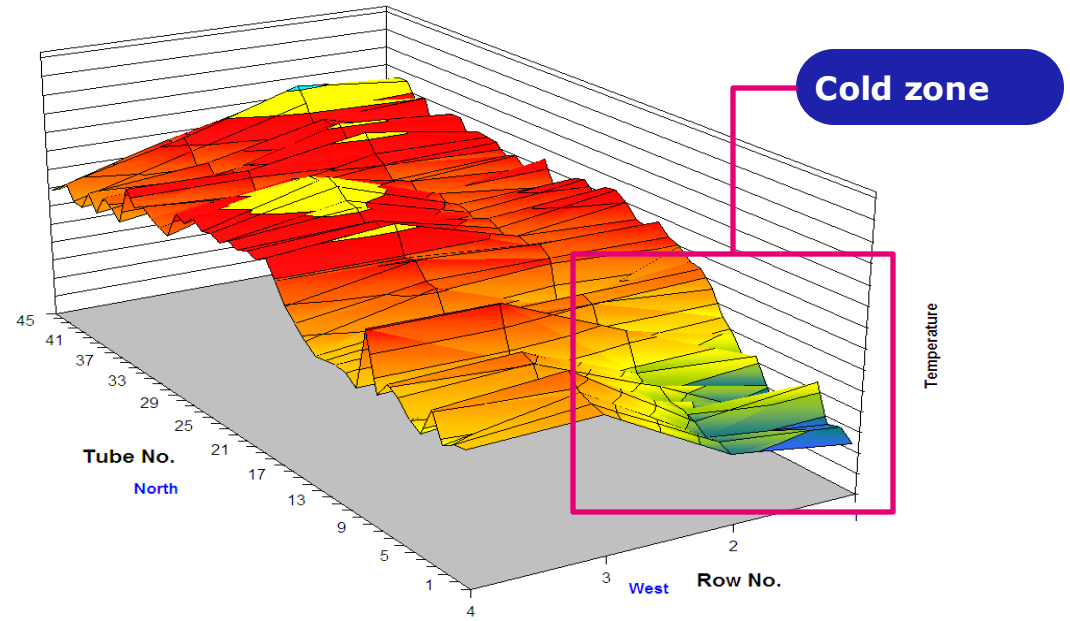


Potential benefits from a reformer survey include:

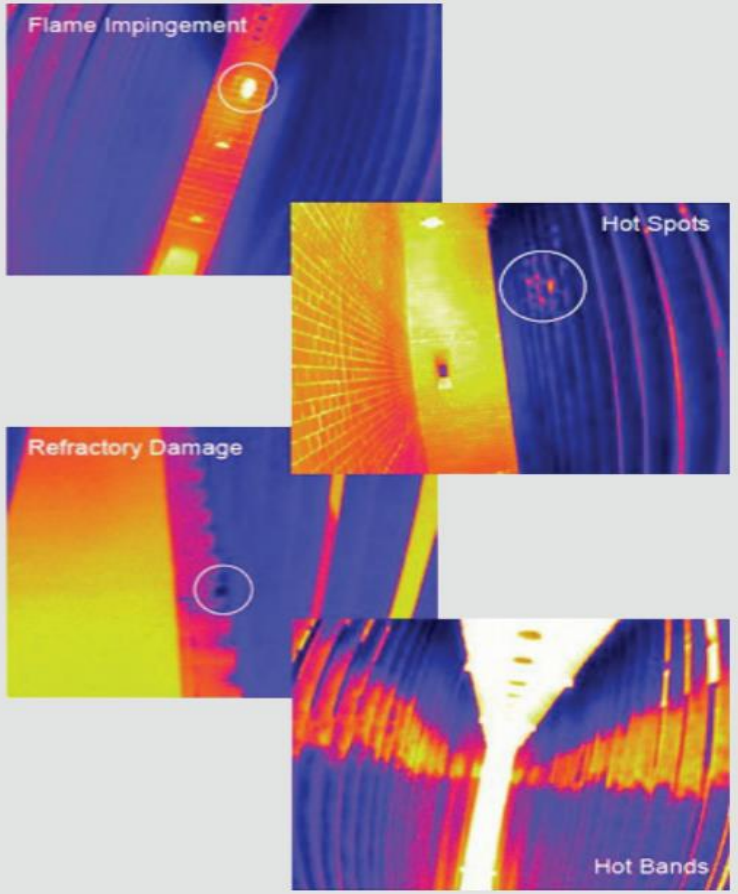
- Validation of local measurements
- Efficiency gains
- Extended tube and/or catalyst life
- Reformer balance
- Benchmarking

Reformer survey output

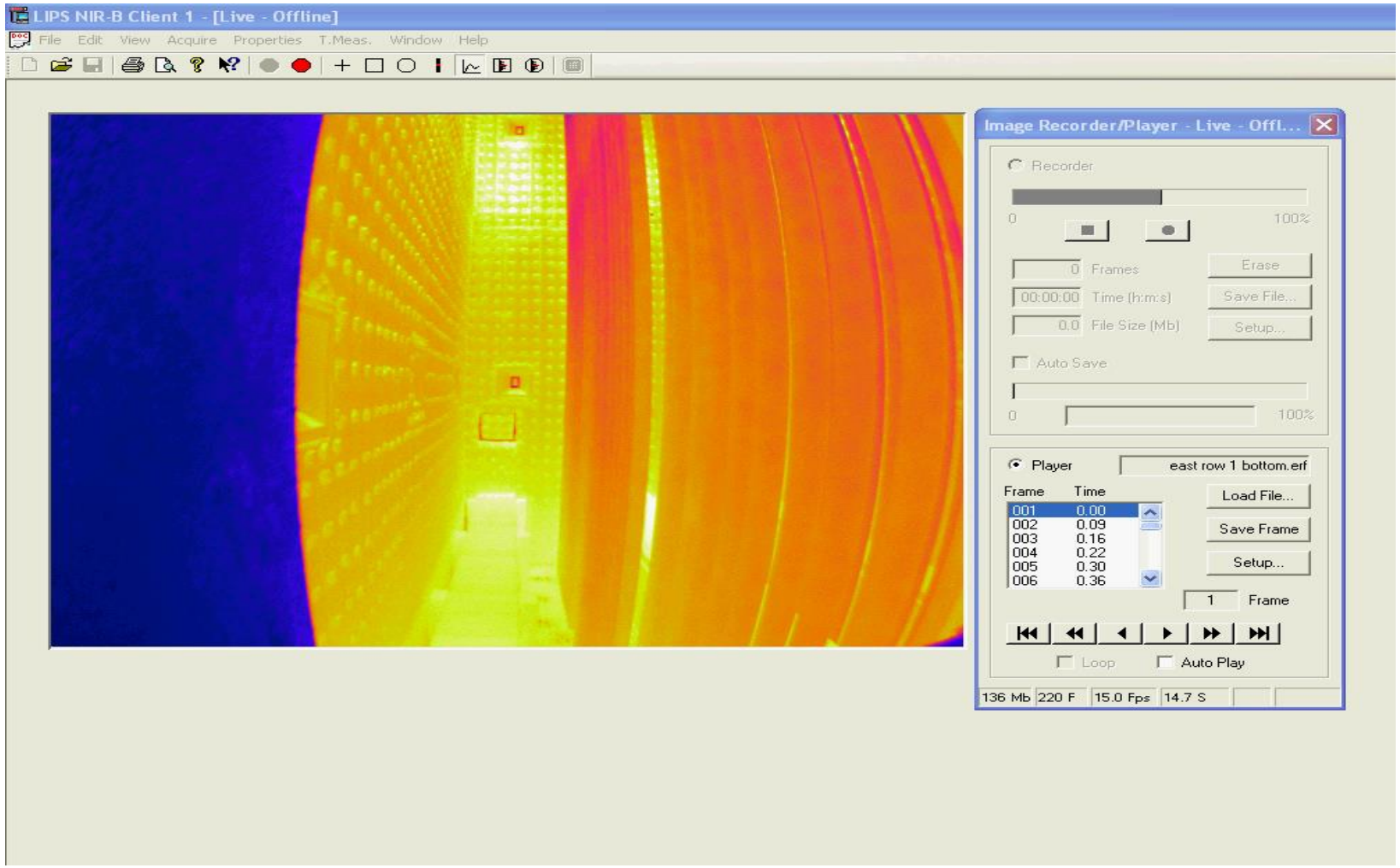
Statistical and graphical analysis of TWT



Troubleshoot operational issues



Reformer imager demonstration – Tube profile



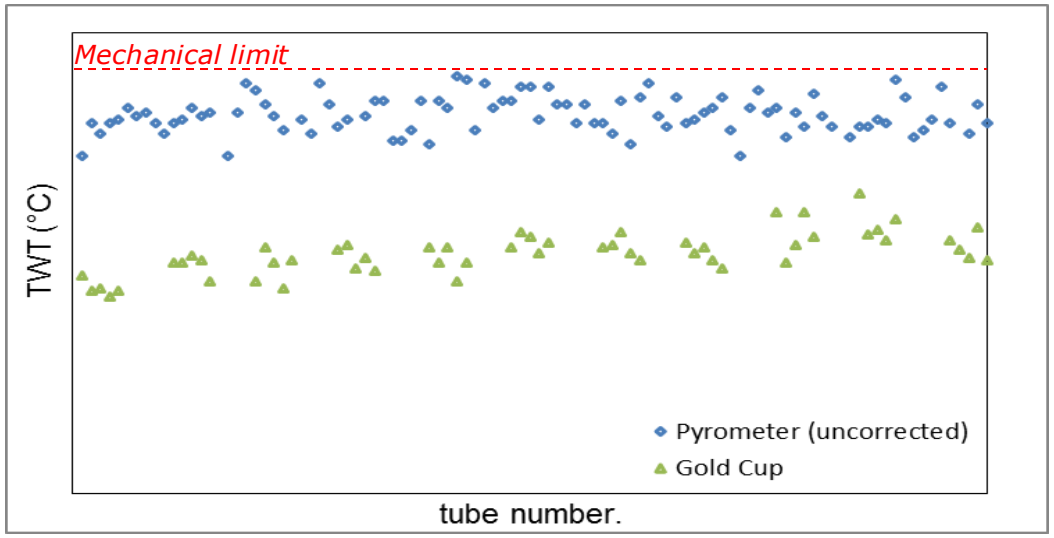
TWT measurement - Contact

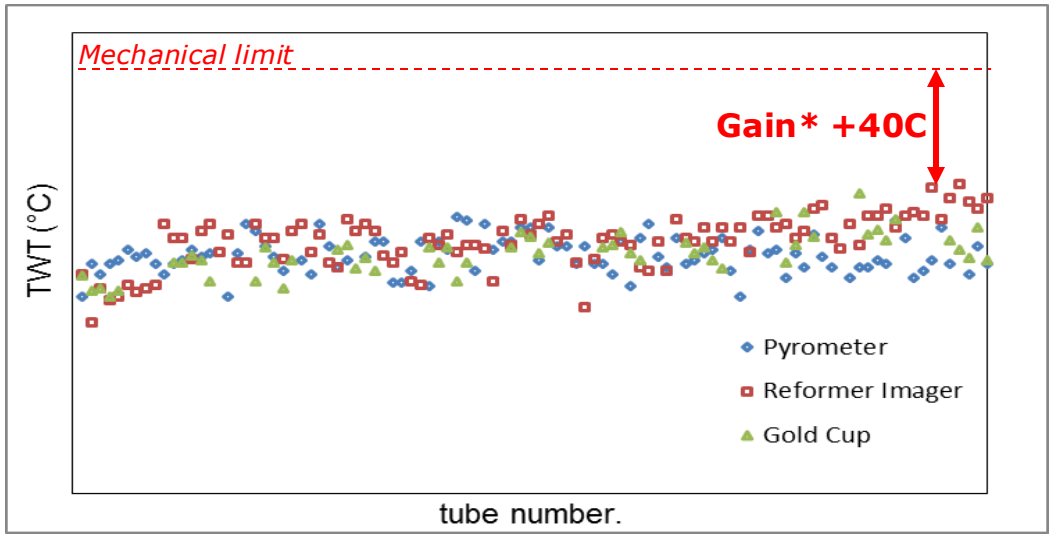
Gold cup pyrometer

- Excludes background radiation
- Allows calculation of emissivity
- High accuracy/reproducibility
- Limited access
- Not used much anymore
    - Confidence in our correction method with Imager.

Tube monitoring: TWT measurement

Case: Customer measured TWT very close to design temperatures. Reformer survey showed that customer pyrometer measurements were largely incorrect.





Raw TWT → Correction algorithm → Actual TWT

***T gain may account for up to 5% H_2 increase at the reformer outlet**

Summary

Monitoring is essential to ensure optimal, efficient, and reliable operation.

Keep in mind:

Plant data analysis is a challenge

- Accurate data is key to modeling the performance of a plant

Visual inspection is key – know what to look for

Tube wall temperature measurements

- Require correction for non-contact methods
- Identify potential plant issues
- Can improve operational efficiency

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