JM

Johnson Matthey
Inspiring science, enhancing life

Improvements in FCCU Operation through Controlled Catalyst Withdrawals

Kate Hovey

Kate.Hovey@Matthey.com

REFCOMM®
VALENCIA
1-4 October 2018

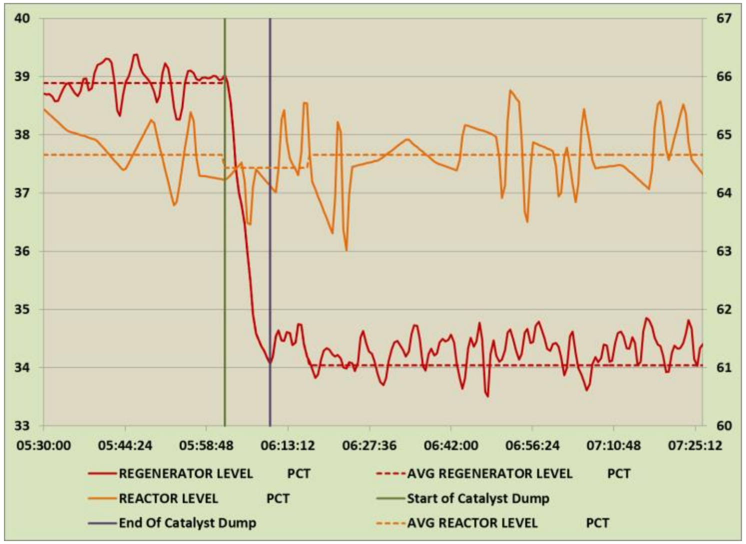
Catalyst Withdrawals in Refineries

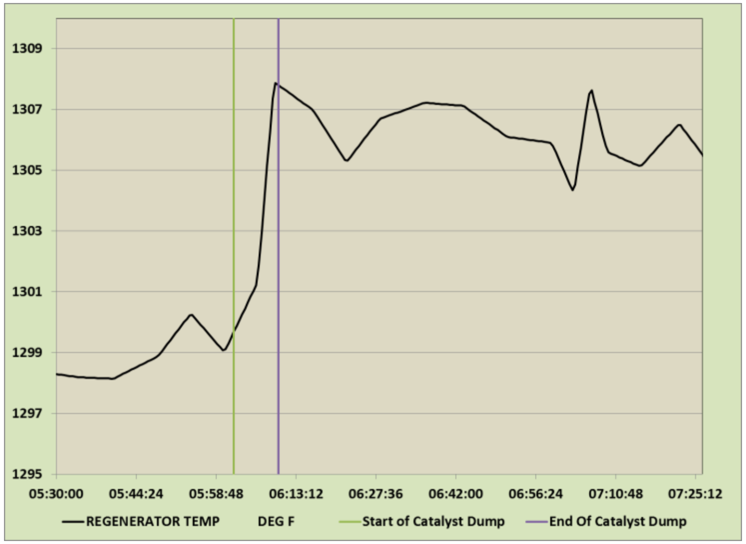
- Most FCC units withdraw catalyst manually, once every few days
- Disadvantages of “batch withdrawal”
  - Poor control of withdrawal rate due to manual adjustments of catalyst and carrier air flows
  - High temperature and poor velocity control results in high erosion rates of valves and piping
    - Risk of hot catalyst exposure
    - Frequent maintenance required
  - Can have a significant impact on unit operation and flue gas emissions

Consequences of Batch Withdrawal

Example 1
Yield Effect

- US refinery example
- Withdrawal made of 5% of Regenerator bed in 8 Minutes
    - 10,500lbs catalyst (5% of total inventory)
    - Withdrawal rate = 3.5% of cat circulation rate
- 7°F rise seen in Regenerator temperature

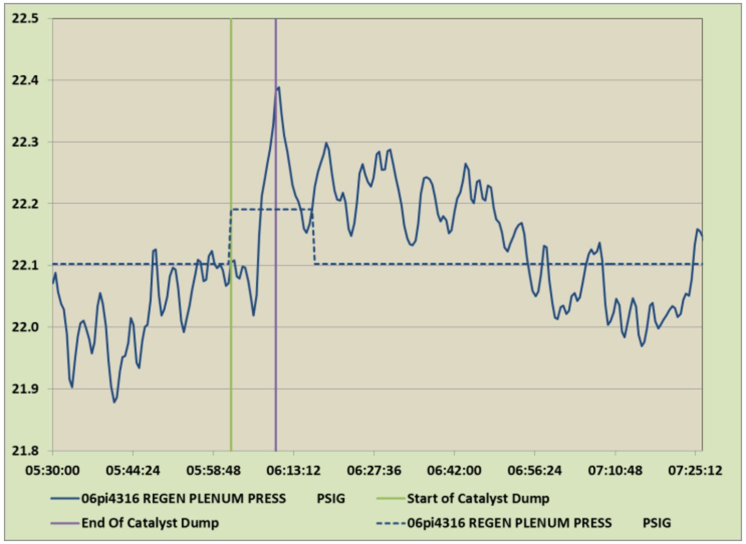


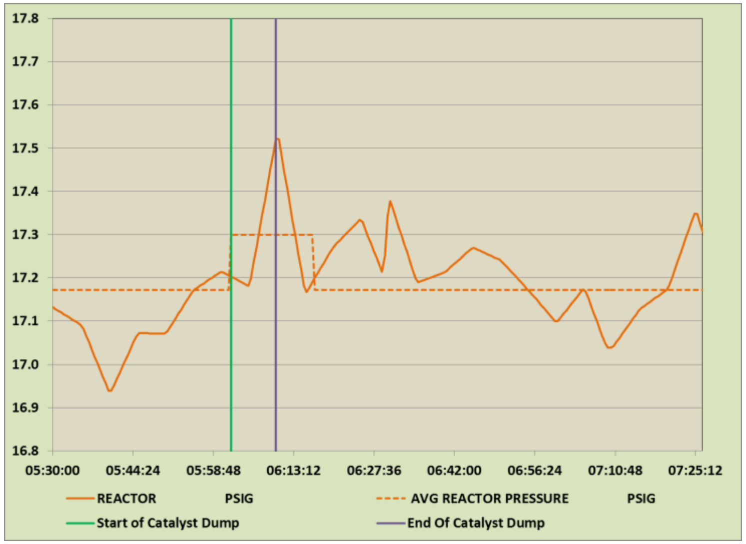


Consequences of Batch Withdrawal

Example 1 (Continued)

- Clear spike in Regenerator pressure during step withdrawal
- Pressure spike affects catalyst circulation, yields
- Steadier FCC Operation leads to higher profitability



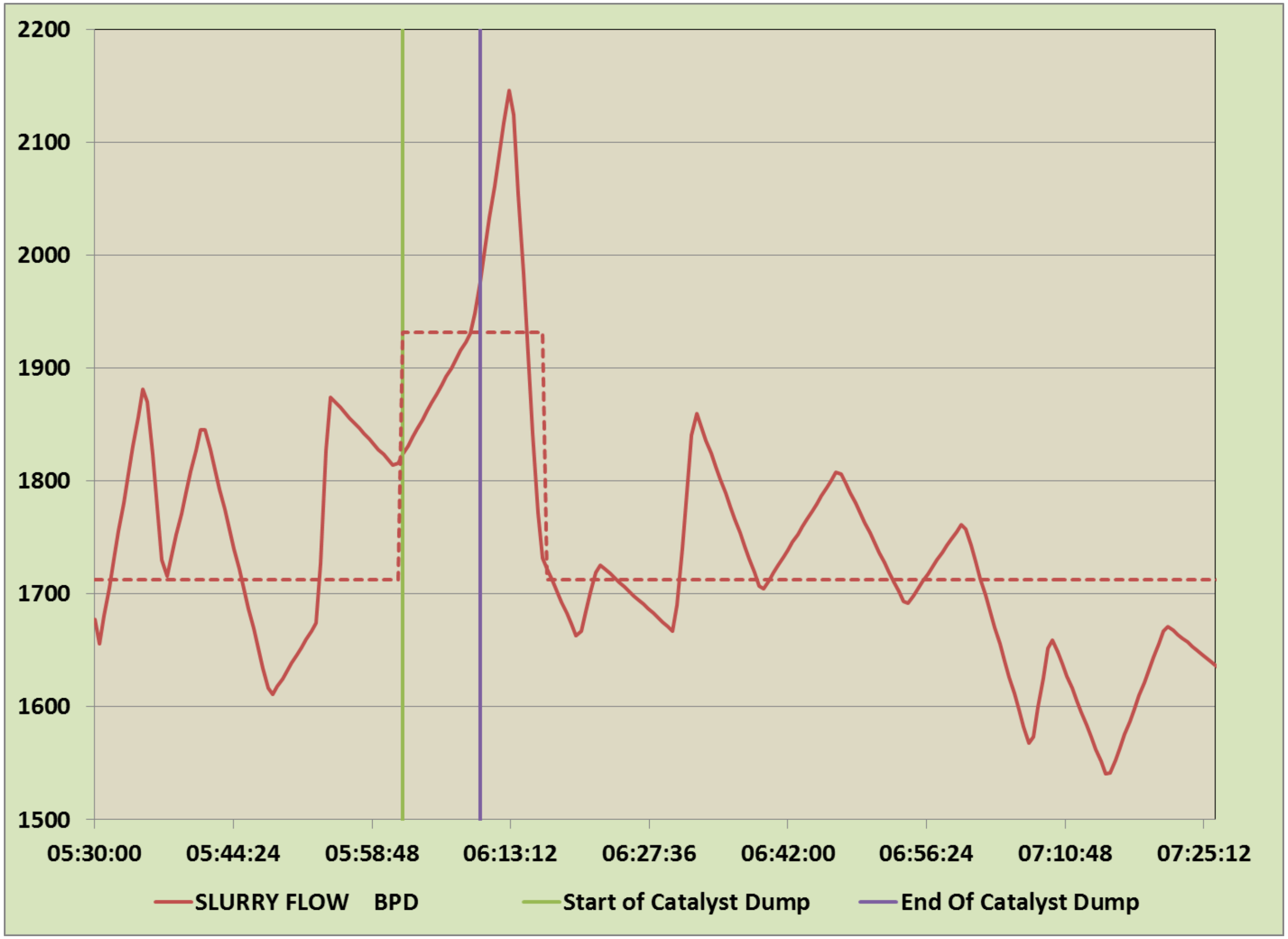


JM

Consequences of Batch Withdrawal

Example 1 (Continued)

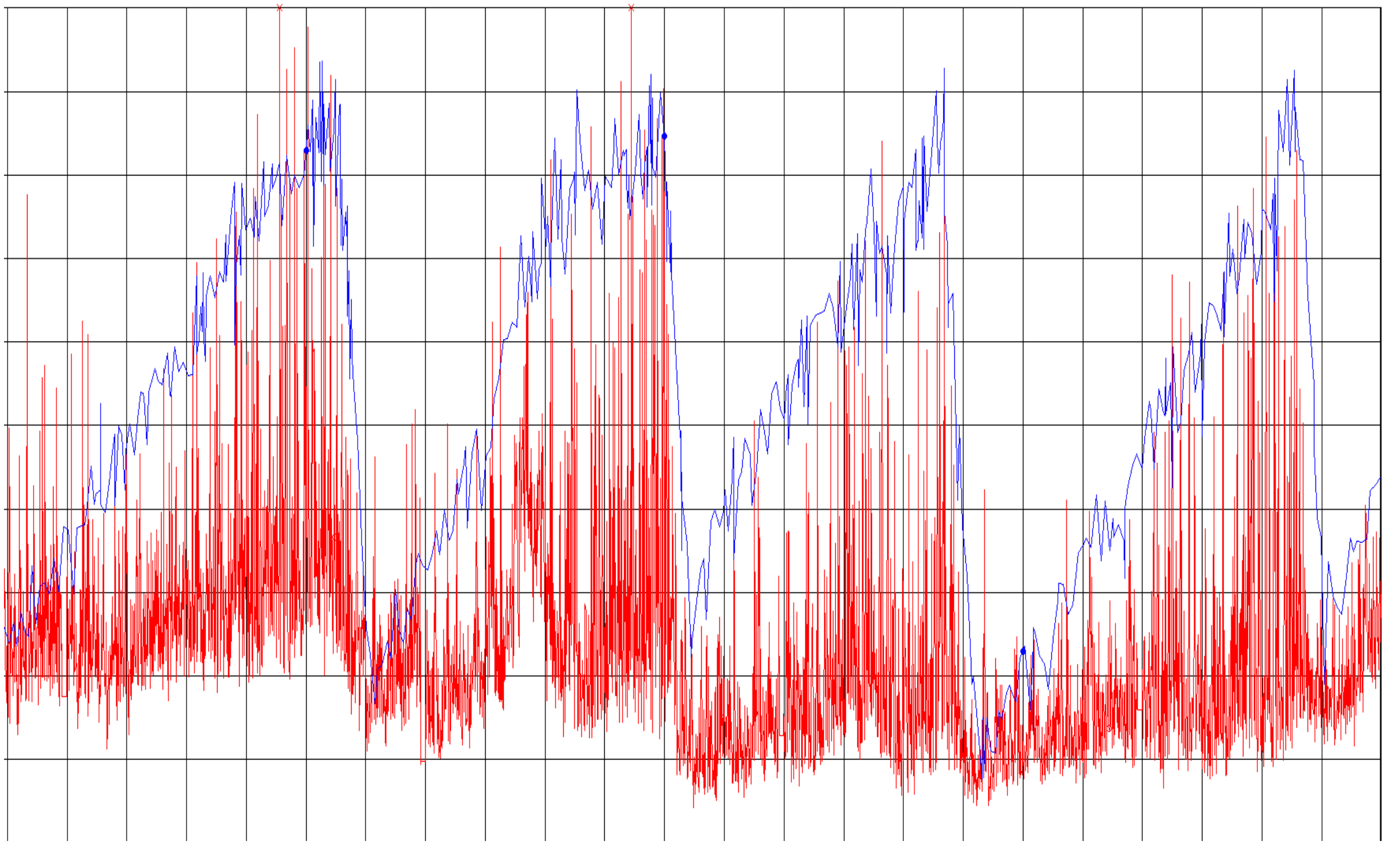
- Withdrawal causes 1% vol increase in Slurry yield
- Duration of upset ~ twice as long as withdrawal period



Consequences of Batch Withdrawal

Example 2

- US refinery example
- As Regenerator bed level increases, CO Emissions increase
- Bed level has a direct affect on Coke burn dynamics and Flue Gas emissions



- Blue Line – Regenerator Bed Level
- Red Line – CO Emissions (PPM)

Manual Catalyst Withdrawals at Marathon Petroleum Garyville

- High velocities lead to piping erosion
  - Safety concern – exposure to hot catalyst
  - High maintenance costs
- Manual withdrawals lead to high temperature catalyst in the E-Cat hopper
  - Potential catalyst truck damage
  - Limits truck loading schedule
- Flexicracker design
  - Overflow well sets Regenerator level
  - Use catalyst withdrawals to control Reactor level
  - Changes in Reactor level/catalyst residence time can affect yields

Further details of this application have been published in the 2017 AFPM Paper AM-17-45

JM's Continuous Catalyst Withdrawal System

Johnson Matthey's design overcomes all main drawbacks of existing systems:

✓ Erosion of throttling device for controlling withdrawal rate is completely eliminated

- Pressure balance design allows use of a simple on/off Everlasting valve
- Easy control of withdrawal rate over a wide range, with tight control

✓ Eliminates large changes in Regenerator bed level

- Withdrawal is continuous, so bed level can be kept constant

✓ Eliminates high velocities in withdrawal piping

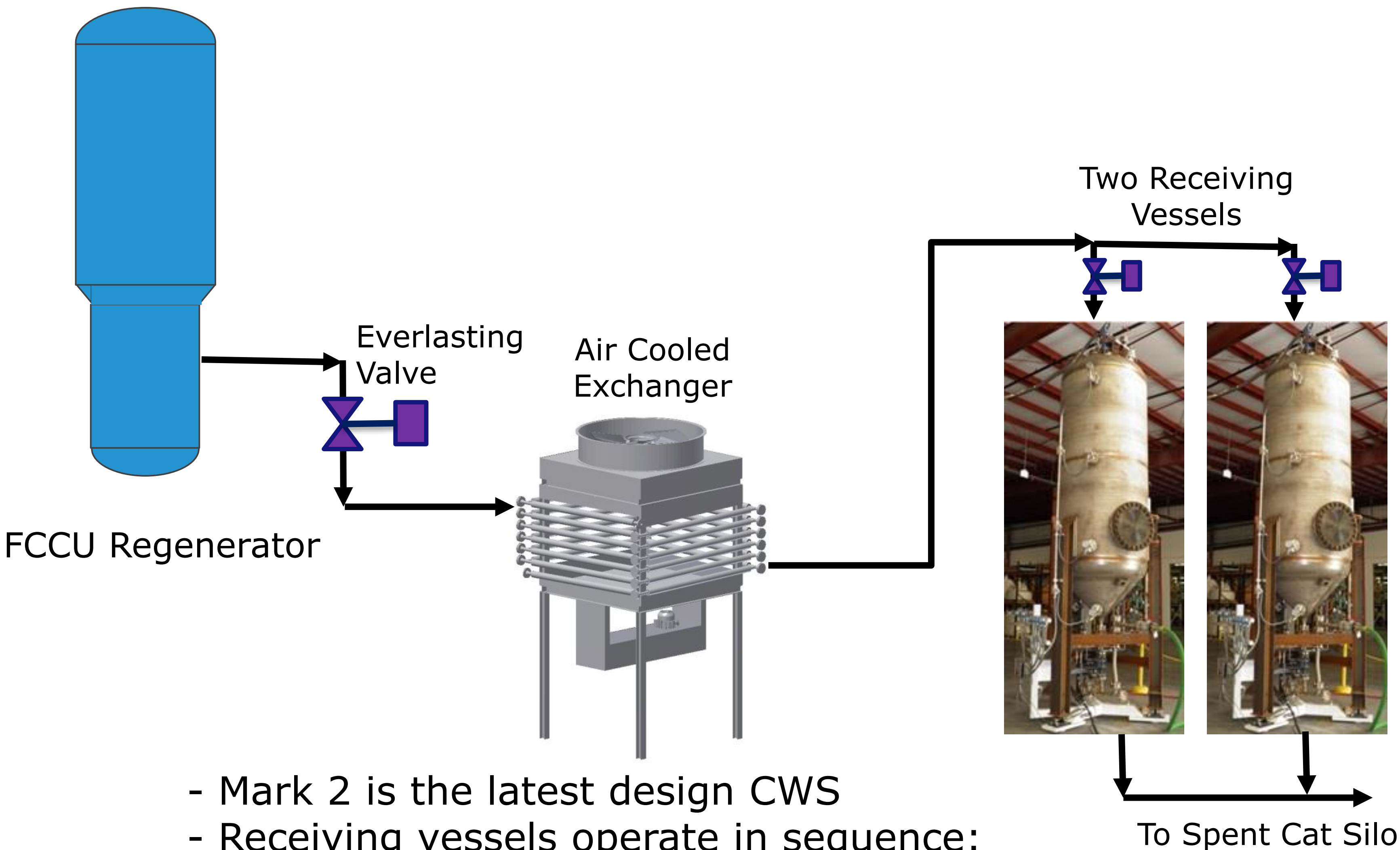
- Line velocity tightly controlled at ~ 25 ft/sec (8-10 m/sec) for minimal erosion

✓ Prevents high temperature catalyst from damaging storage vessels

- Withdrawn catalyst is cooled before being transferred to storage

JM

Mark 2 Catalyst Withdrawal System Flow Scheme



- Mark 2 is the latest design CWS
- Receiving vessels operate in sequence:
  - One is filling, while the other is emptying
  - Switchover between vessels is fully automatic.

JM

Summary of Operating Principles

- Cooling is always at maximum for lowest outlet temperatures
  - Catalyst temperature depends on withdrawal rate only
- The catalyst flow is controlled by the pressure balance between the regenerator and receiving hopper.
  - Catalyst valve is either fully open or fully closed – not regulating!
  - Flowrate is controlled by adjusting receiving vessel pressure
  - Vessel pressure control valve is on clean side of filter for maximum reliability
- Withdrawal line velocity independently controlled using carrier air
  - Velocity in withdrawal line should never exceed ~ 25 ft/sec
- Receiving vessels automatically switch over when they reach a preset level
  - One is always receiving catalyst while the other is emptying, and then standing by to switch back over again
- Control based on proven IMS (INTERCAT™ Management System) technology

JM

Latest Features of the Mark 2 Design

- The CWS Mark 2 incorporates a number of novel design features to improve efficiency and reduce cost
- The Catalyst Withdrawal System uses a novel heat exchanger design
  - Significantly reduced footprint compared to earlier designs
  - Increased flexibility in metallurgy
  - Costs are minimised due to induced fan design
- Efficient cooling allows use of carbon steel receiving vessels
  - Two vessel design eliminates need to stop withdrawal during discharge mode
  - Reduces cyclic thermal stresses

Initial prototype design - Mark 1

- Installed at the Marathon Garyville Refinery in 2015
- The CWS has been in continuous operation since 1st quarter 2016
- Catalyst being withdrawn continuously under delta P control
- Capacity proven up to 22 TPD, now controlling at 3-5 TPD
- Outlet temperatures lower than design
  - Being cooled to <100°C
- Line velocity tightly controlled at ~15 ft/sec
- Accurate weighing of catalyst via load cells
- Unit is exceeding design expectations

JM

Catalyst Withdrawal System Setup

- Withdrawal system has 2 major components:
  - Cooling skid – Ambient air is used to cool the catalyst through exchangers
  - Vessel – Collects and weighs withdrawn catalyst

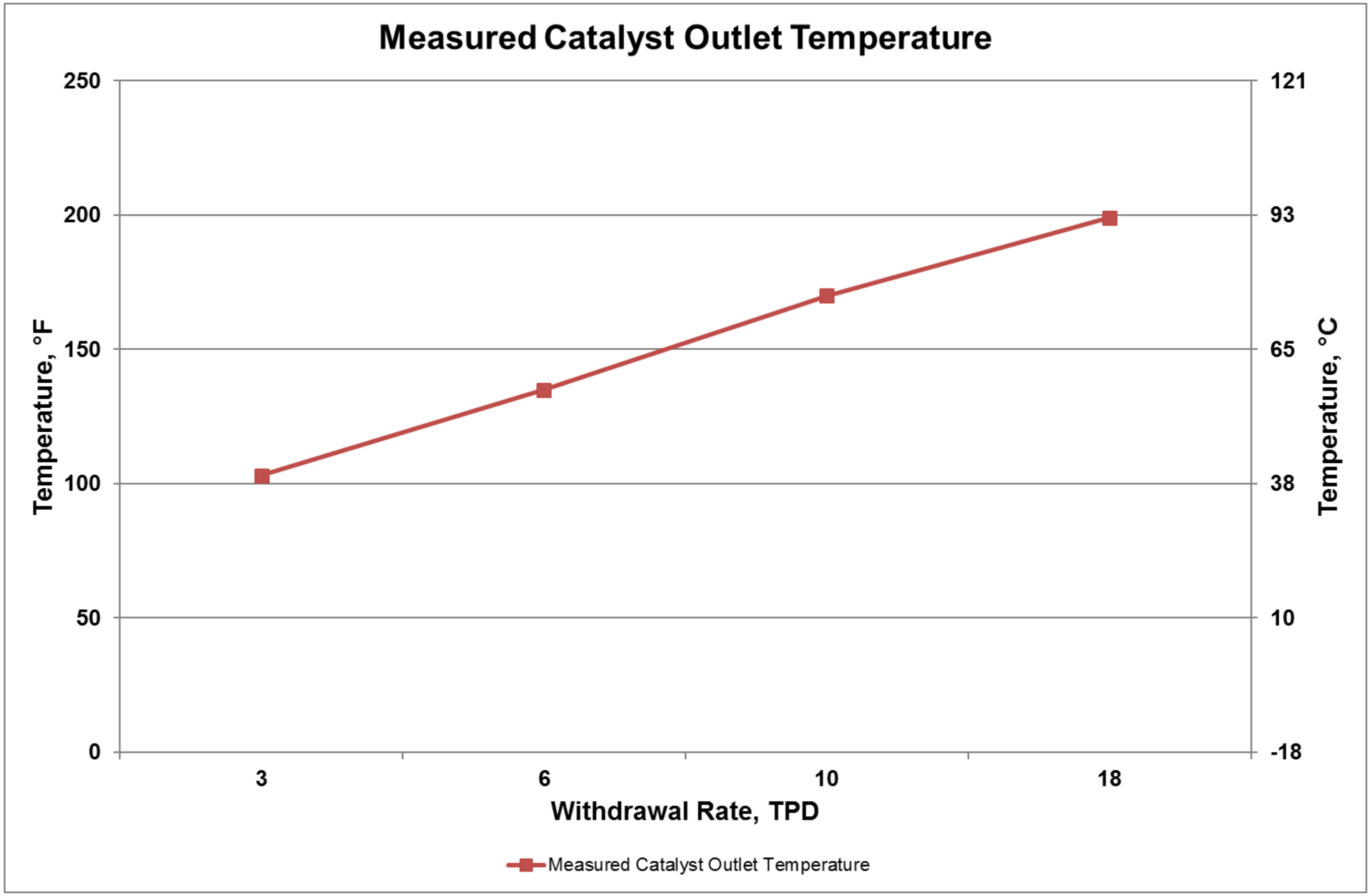
Vessel

Cooling Skid

Feedback from Startup

- Overall design concept has been shown to work extremely well
- Close coordination with refinery project/design team, and detailed design reviews are crucial
- Design of take off point on Regenerator is extremely important
  - Prevention of dead zones, control of purge flows
  - Maintain head of catalyst in vertical run from Regenerator
- Heat transfer coefficients were much higher than originally assumed
  - Will allow for improved layout of future withdrawal systems

Outlet Temperature Profile

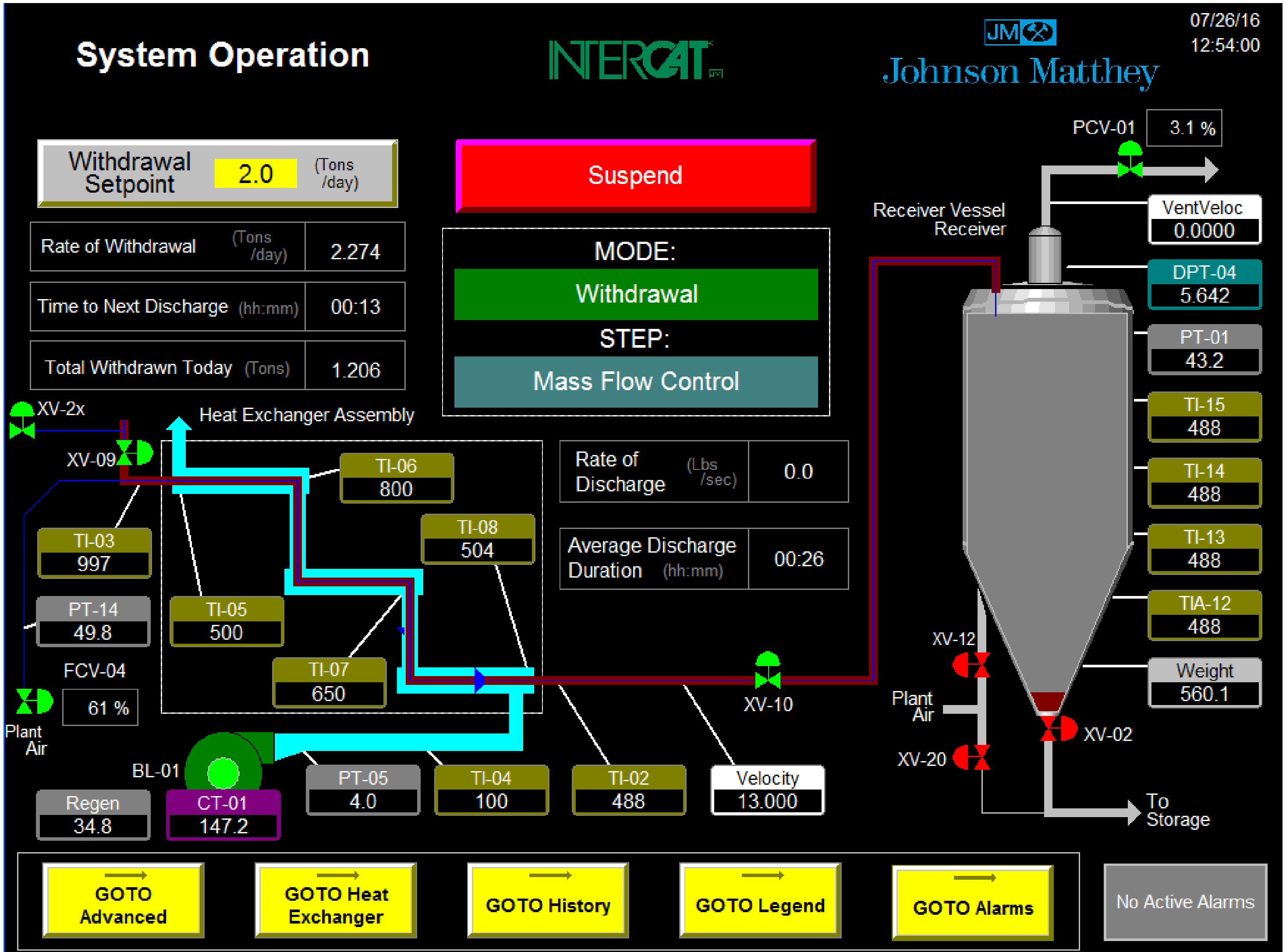


Lower outlet temperature than design!

Operating the Catalyst Withdrawal System

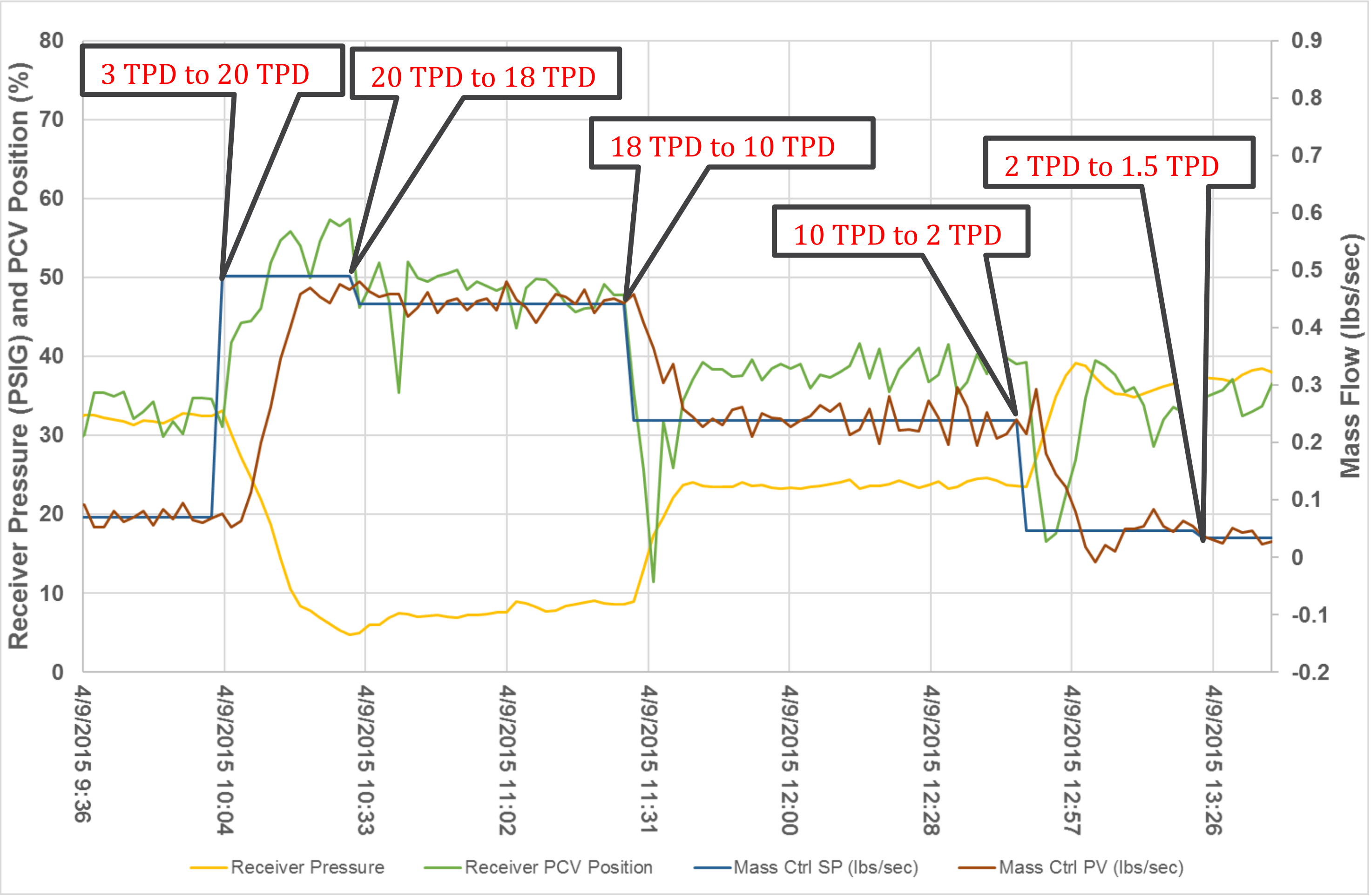
Set it and forget it!

The CWS Controller can be integrated with the Refinery DCS to allow direct control of the catalyst level.



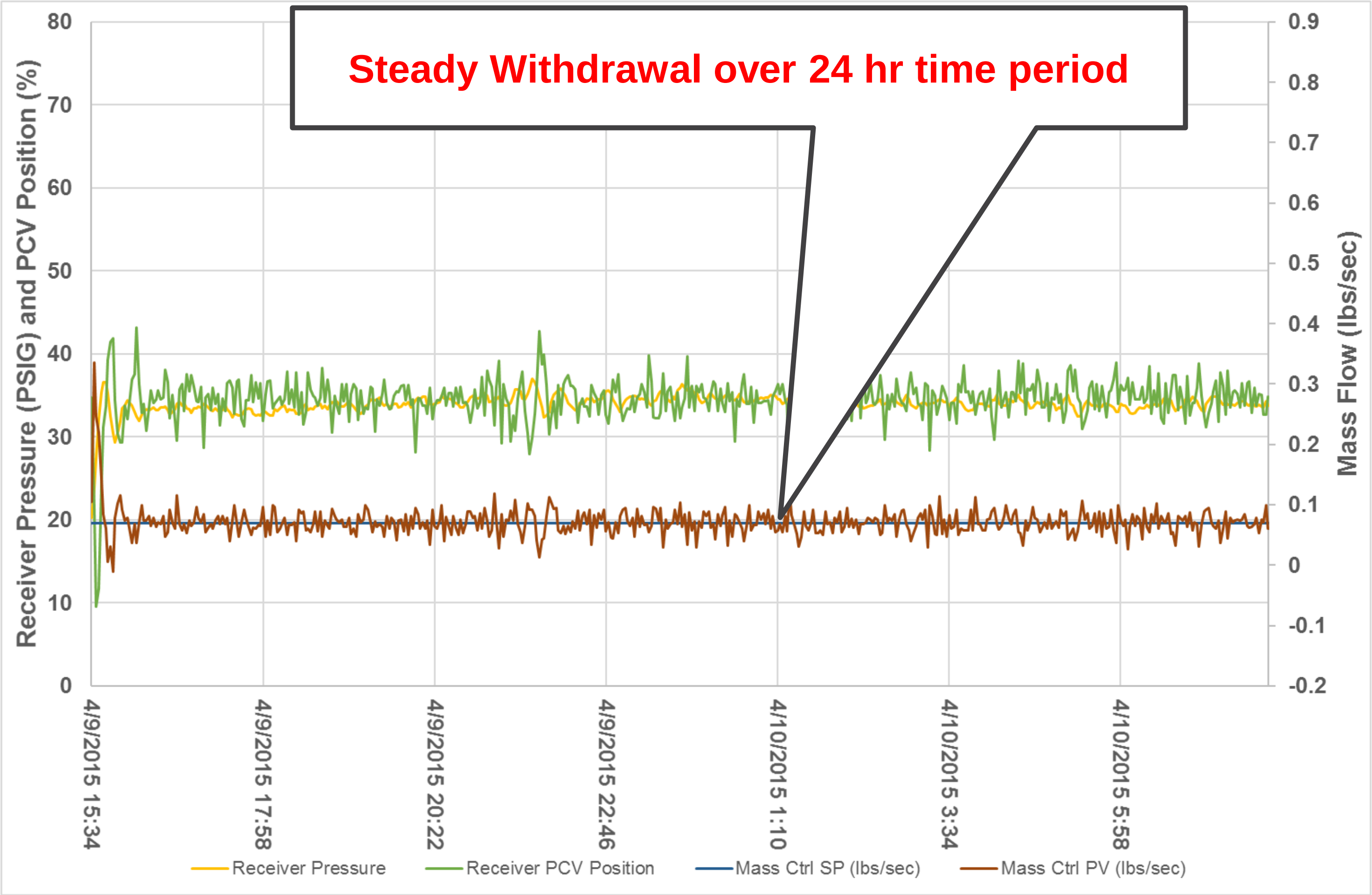
System Responds Well to Rate Changes

- Catalyst Withdrawal System tested at varying withdrawal rates
- System responded well with rates varying from 1.5TPD to 20TPD



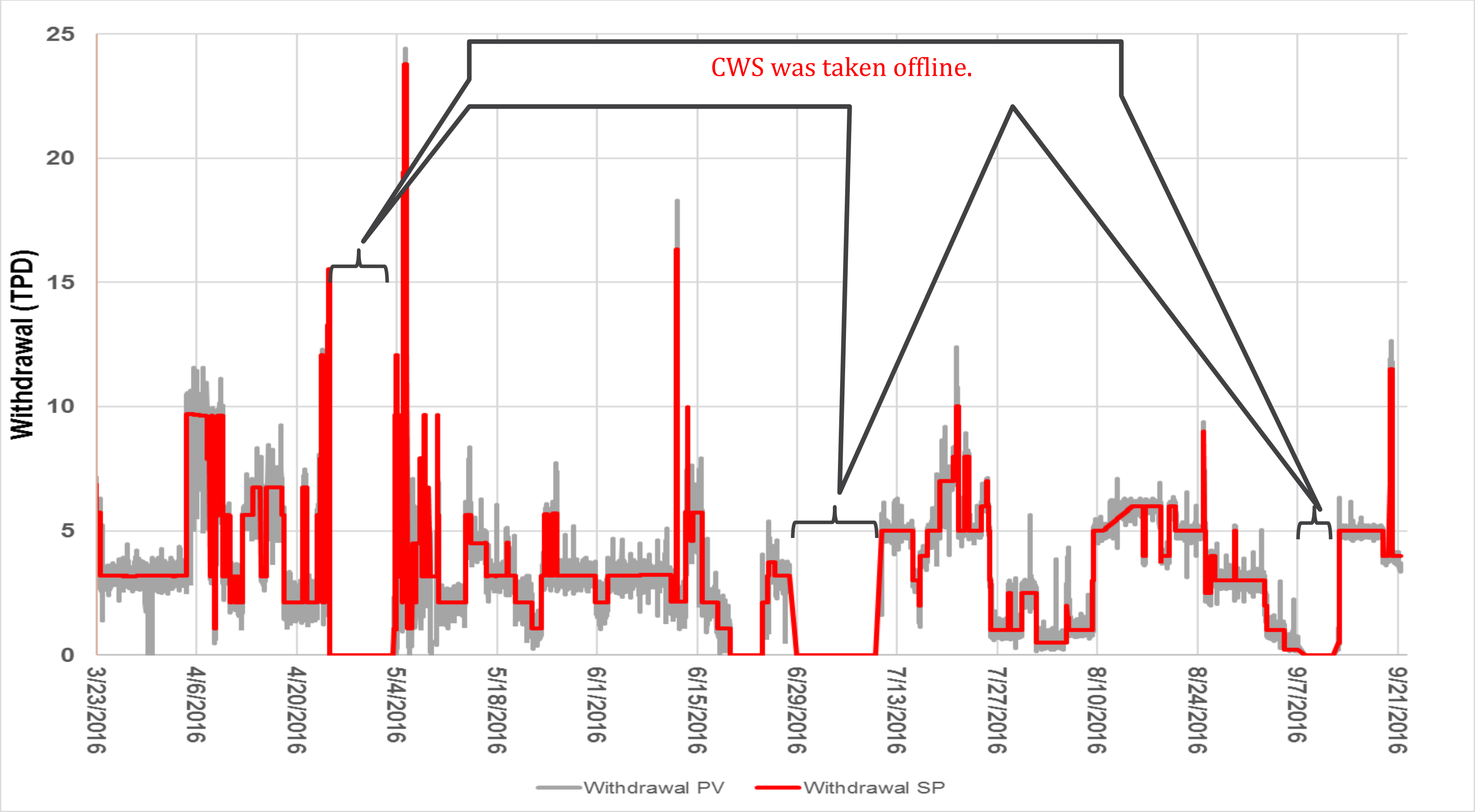
JM

Steady Withdrawal Rate with Withdrawal System



The system controls well at steady state, minimal fluctuations from set point

Withdrawal System Operation

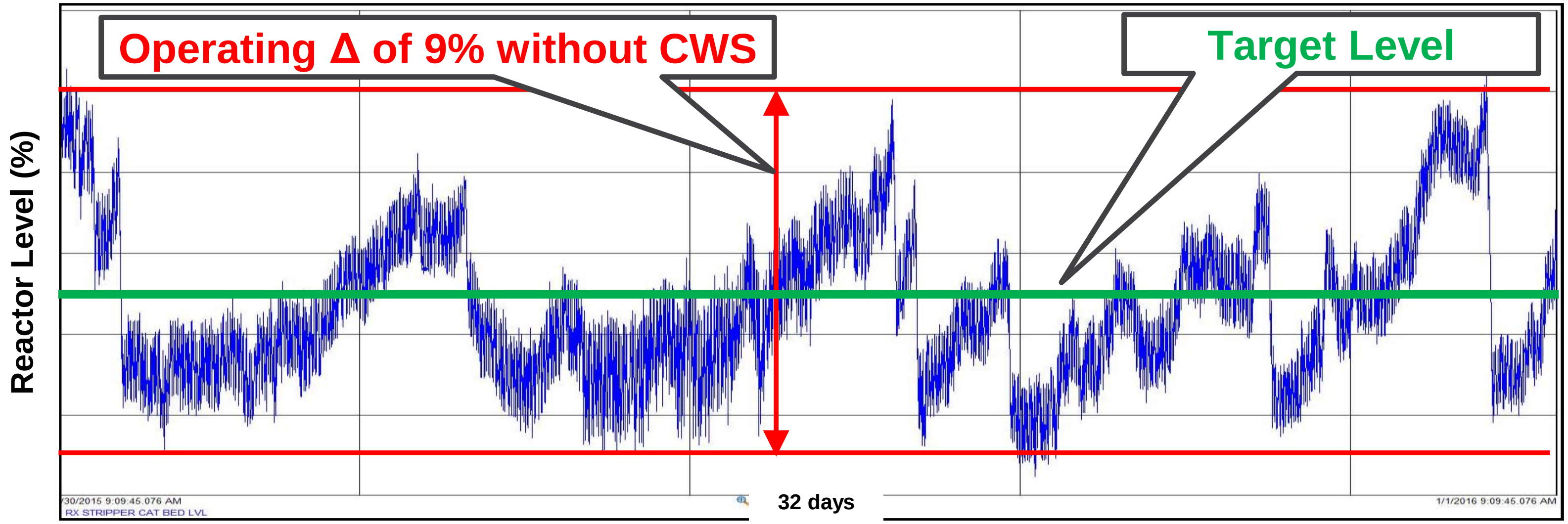


- Making manual rate adjustments to control Reactor level
- System has been operating well now for an extended period of time, ~1 year

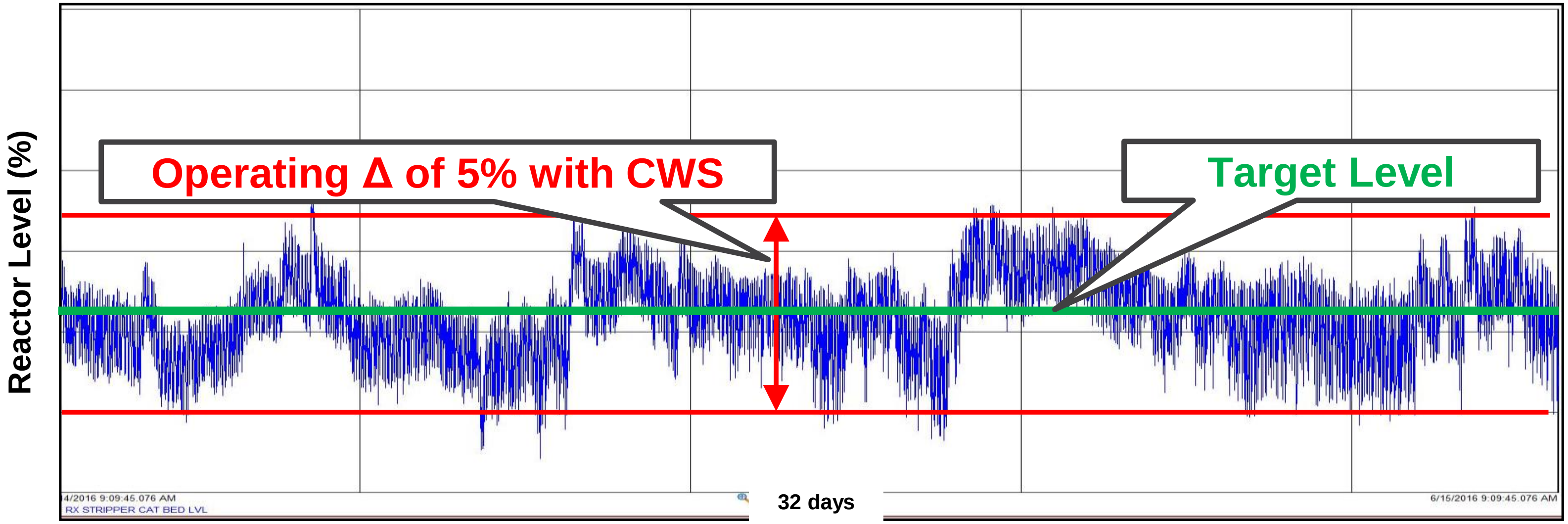
Reactor Level Control

Withdrawal rate can be set manually or controlled via refinery DCS

Without CWS



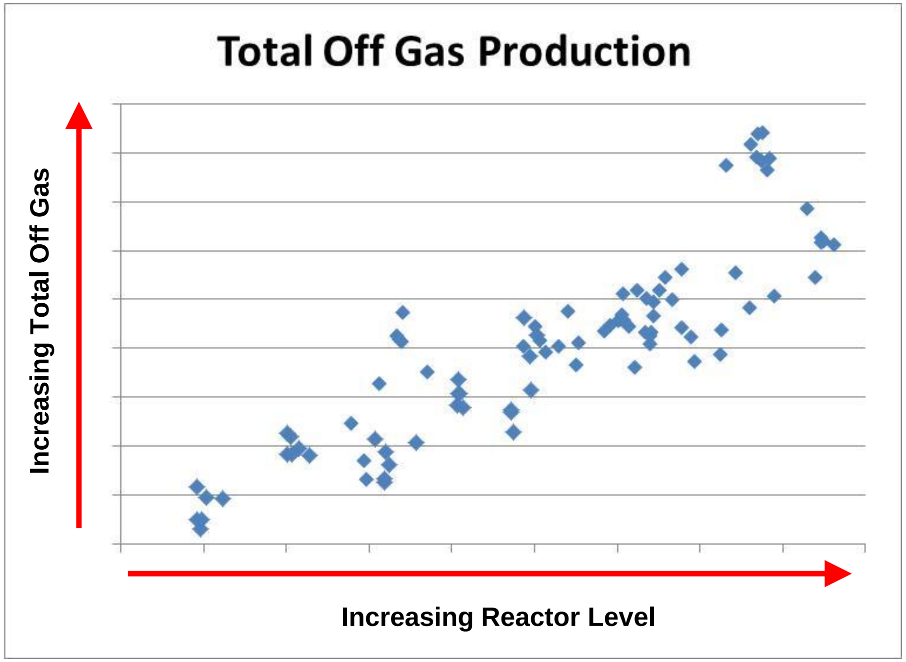
With CWS



Reactor Level Test Run - Marathon Garyville

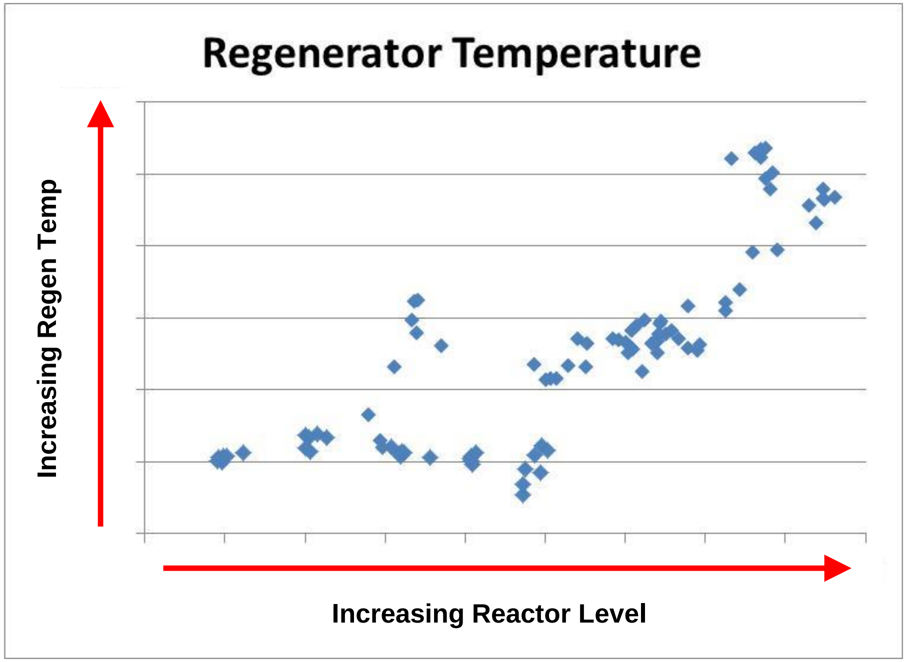
- Reactor level step testing was performed using the Catalyst Withdrawal System to hold a stable Reactor level at each step
- Seven (7) different Reactor levels were tested with feed and product sampling at each level following a hold period
- Changing catalyst levels/residence time can impact yield profile
- Optimum Reactor level was determined based on yield comparisons
- Catalyst Withdrawal System allows for a reduction in Reactor level variability
  - 2.5% deviation compared to 4.5% deviation from optimum level
- Yield improvements were observed when operating closer to the target Reactor level

Reactor Level Test Run - Marathon Garyville



- Total off gas production changed as Reactor level was changed

- As delta coke decreased, Regenerator temperature also decreased – leading to an increase in catalyst circulation and catalyst/oil ratio, which improves yields



Final Summary

- Johnson Matthey's Mark 2 Catalyst Withdrawal System technology is the latest design
- The initial Mark 1 design has been successfully proved at Marathon Petroleum's Garyville Refinery
  - Tight control of withdrawal line velocity
    - Improves safety, reduced maintenance
  - Effective cooling of catalyst
    - Safety & truck loading flexibility
  - Controls FCC Catalyst Level
    - Improved yields
- Marathon presented a paper on this at the 2017 Spring AFPM Meeting (AM17-45)
    - Project payback was reported to be < 1 year
- The improved design features of the Mark 2 design both increase efficiency and reduce overall costs