Monitoring Transient Operations

Learning Objectives

Provide an overview of each Practice Share in this section

Demonstrate tools to improve unit monitoring.

Use of checklists in operating procedures

Flavor · Practice Shares

FCC Standby Operations Monitoring Checklist

FCC Oxygen Monitoring During Standby Operations

FCC Shift Handover Checklist while in Standby

FCC Simplified DCS Screen for Standby Operations

Deep Dive · Key Monitoring Variables

Key variables and challenges with monitoring during standby operation.

Exercise · Simplified DCS Screens

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Flavor Standby Operations Monitoring Checklist

FCC Unit leaders prepare clear guidance, in advance, on the important monitoring parameters during non-routine operating mode.

Includes intended target values for key parameters.

Focus is to reduce risk of air/ hydrocarbon mixing.

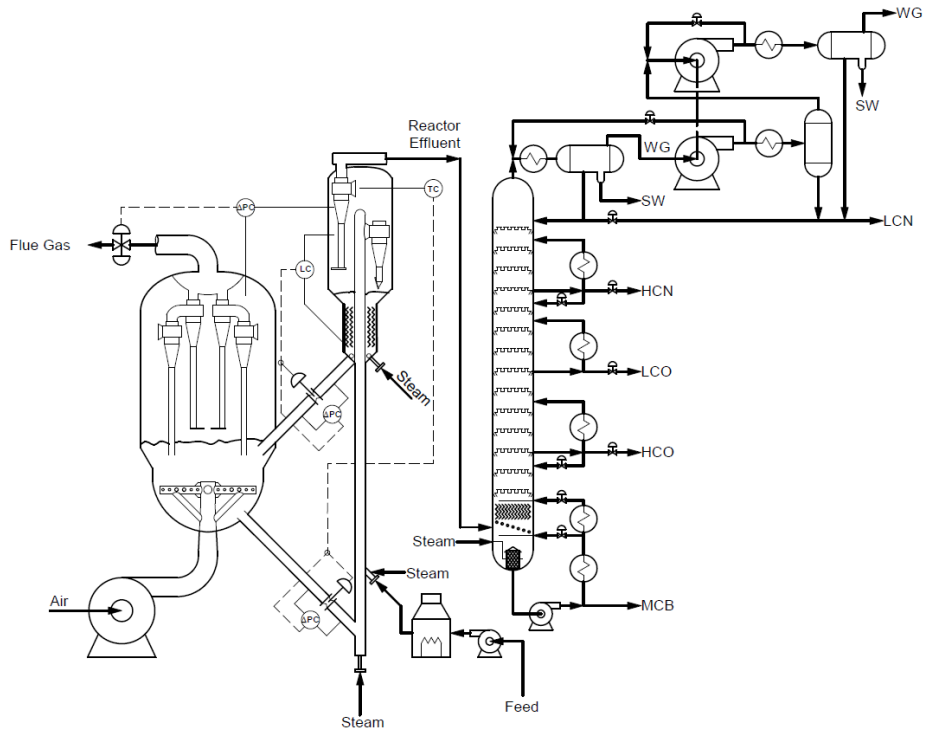
This list will be referred to as a "Standby Checklist" – intent is to supplement standard operating procedures.

Operations team will use the list to guide monitoring activities and frequency to be performed while the unit is in a non-normal/ standby operating mode.

Standby Operations Monitoring Checklist

Operating modes and implementation include many items for consideration, including:

- Duration of standby
- De-inventory and ambient/ freezing temperature concerns
- Steam/water management
- Selected isolation points
- Main column pressure control and temperature
- Reactor/Regenerator and slide valve pressure balance
- Inert gas flows
- Main column bottoms level
- ESP safety



Standby Operations Monitoring Checklist

Standby Checklist

Parameter	Tag	Target	Time											
Spent or Regen Slide / Plug Valve %OP	Tag #	Stable, trends with the valve's dP	**%OP**											
Spent or Regen Slide / Plug Valve %OP positioner	N/A	Consistent with its OP	**PV=**											
Spent or Regen Slide / Plug Valve dP	Tag#1 Tag#2 Tag#3 Tag#4	Stable, pressures track together	**Y/N**											
Check group of unit specific differential pressures	Tag#1 Tag#2 Tag#3 Tag#4	Stable, pressures track together	**Y/N**											
Reactor or Regenerator Pressure	Tag #	Stable trend	**Y/N**											
Reactor or Regenerator Bed Level	Tag#1 Tag#2	Stable, tracking together	**Y/N**											
Reactor or Regenerator Bed Level %OP	Tag#1 Tag#2	Stable, PV tracking with OP	**PV=**											
Check Unit Specific Process Variable (PV)	Tag #	Target Value or operating range	**PV=**											
Check Unit Specific Situational	Tag #	Target Value 2 or operating range	**Y/N**											
Check Unit Specific PV and Valve Output for Stable Operation	Tag #	PV and OP Stable	**Y/N**											
Check Unit Specific Stable PV	Tag #	PV Stable	**Y/N**											

To facilitate the user's application of this practice to their own unit an example Standby checklist is provided below for use as a starting point for development of their own unit specific checklist.

Flavor Oxygen Monitoring During Standby Operations

Purpose of Practice Share: Practices for monitoring oxygen (O2) concentration in the FCC main column overhead system during unit startups and shutdowns.

Air/oxygen ingress to the FCC Reactor and downstream equipment is inevitable when circulating catalyst from a regenerator containing high levels of excess oxygen.

It is possible to measure an oxygen concentration in areas where it may accumulate, giving the opportunity to purge it out and mitigate potential hazards.

Non-condensable purge streams are added to the main column to protect the overhead and downstream equipment (typically fuel gas or nitrogen)

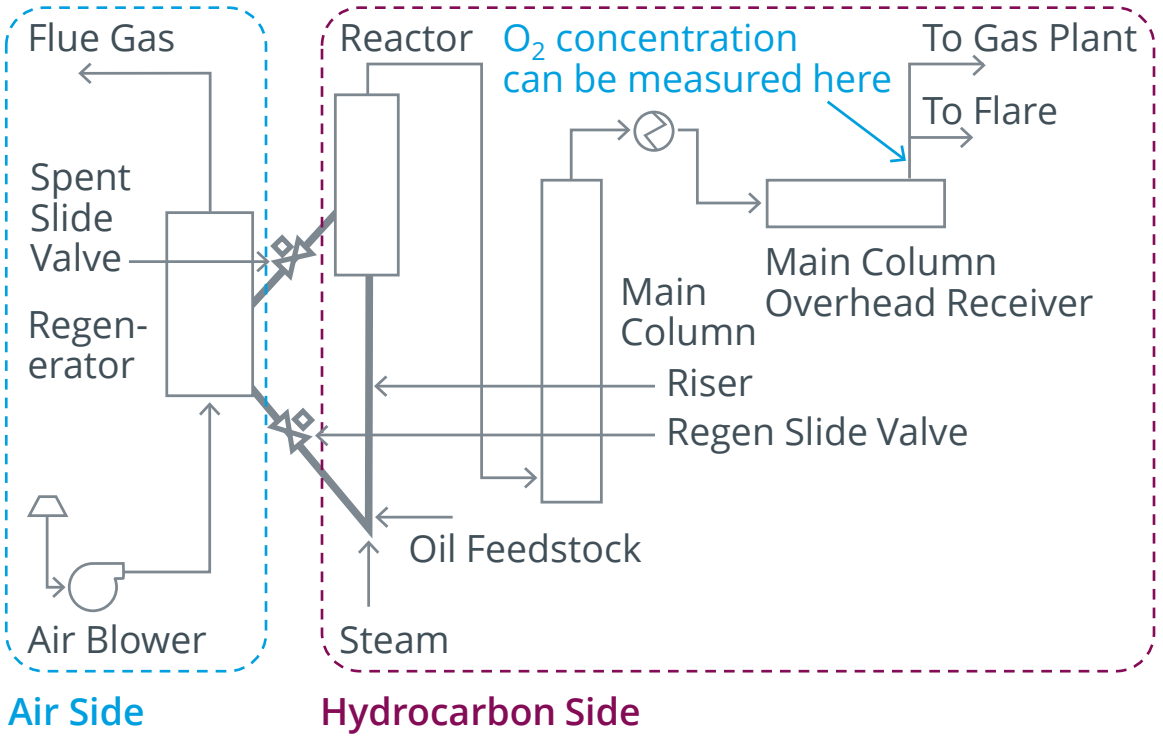


Figure 1. Sampling location for monitoring O_2 in an FCC during non-normal operation.

NFPA 69 lists some guidelines on frequency IF continuous monitoring not used.

Oxygen Monitoring During Standby Operations (cont)

Oxygen Monitoring

Refiners have used outside contractors for monitoring during start up and shutdown with continuous monitoring.

Refiners have used portable gas monitors or other on-unit analytical techniques to monitor O_2.

Results get recorded and tracked through the shutdown and start up activities with clear actions defined to keep oxygen values below defined thresholds.

O_2 monitoring in the FCC main column overhead stream during non-normal operation.

Estimating **Carry Under of Oxygen to the Riser/Reactor and Main Column**

Carry Under (SCF/hr.) = CCR/ ρf * Σ x (520/T) x (Pa/14.7)

Where:

∑ = Voidage = 1 - ρf/ρs

ρf = flowing density in regen standpipe (lb./ft3)

ρs = Skeletal Density (~164 lb./ft3)

CCR = Cat Circulation Rate (lb./hr.)

T = Regen bed temp. (oR)

Pa = absolute pressure in regen standpipe, typically above slide valve (psia)

CCR is catalyst circulation rate during start up and shutdown. If unknown, can use 20% of typical circulation rate.

Typical regenerator standpipe operations are > 75% voidage.

>75% vapor volume by flow.

Do calculations for YOUR specific FCC.

Typical FCCs can see > 4000 SCFH of high oxygen content flue gas carry under to the riser/reactor and main column.

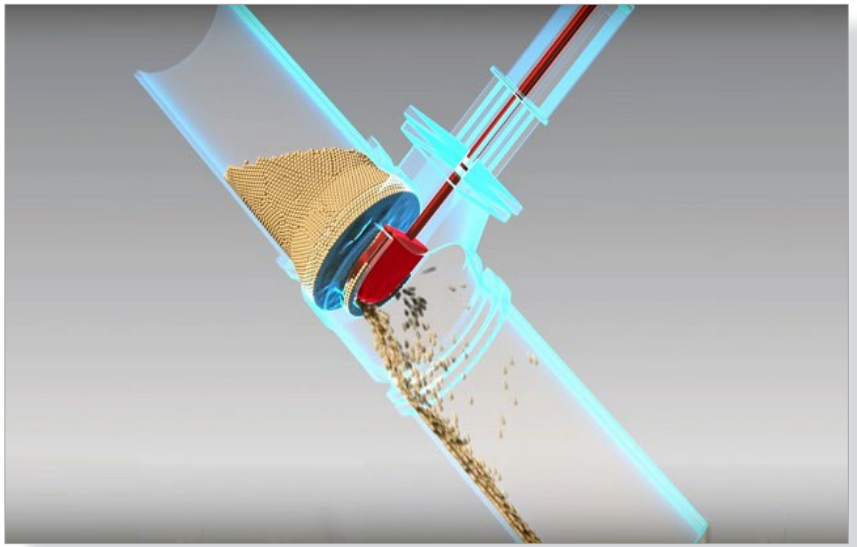


Figure 3. Image from CSB – Not entirely accurate in this context but illustrates the idea of voidage. The most-dense catalyst phase is mostly vapor.

Estimating **Purge Rates of Non-Condensable Gas**

The minimum purge requirement can then be approximated from the following formula, which conservatively assumes the carry under gas is concentrated, dry air (20.9 vol% O_2):

Min Purge (SCF/hr.) = Carry Under (SCF/hr) * (20.9 – O_2Max) / O_2Max

Where:

O_2Max = Target max O_2 concentration after purge

If 4000 SCFH is the estimated carry under gas rate, and you target 4% O_2 maximum concentration, the estimated purge rate needs to be approximately 17000 SCFH.

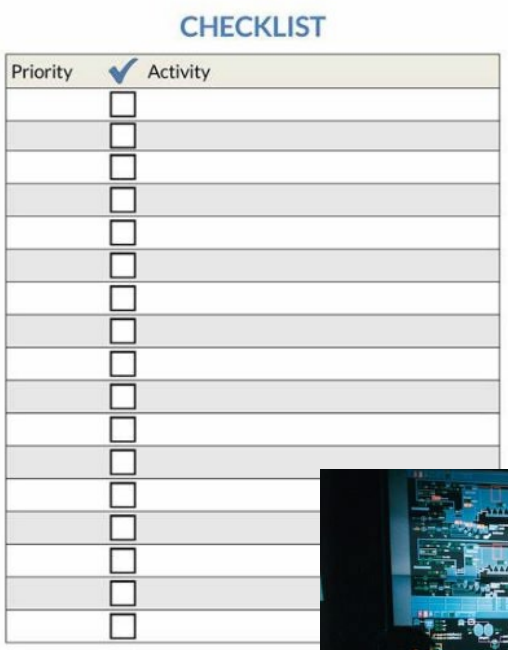
If you do not have this information available, do these calculations prior to the next outage, but VERIFY conditions are close in each outage. Changes in pressure and temperature matter.

Important: Adjust actual non-condensable purge rates based on the routine oxygen monitoring checks at the main column overhead receiver area.

Flavor Shift Handover Checklist While in Standby

Used in conjunction with Standby Operations Monitoring Checklist and ideally, a site- specific simplified DCS screen for unit monitoring.

When in non-routine operations, some protective safeguards may be bypassed (SIS, etc.) while other safeguards are put in place that are monitored and maintained by console or field operations personnel.



Shift Handover Checklist
Console Operator

Covers major points that can arise during the operations shift in 'standby' operation.

May be different for your specific site.

Provides a check for important information being shared during shift change.

Console FCC Operator	Yes	No	Comments
SIS status changes			
Downstream equipment changes			
Any operating procedure variances			
Any steam or N2 purge changes			
Any changes in the pressure balances between regen/reactor/fractionator/flare			
Any new instrument malfunctions			
Any change in Rx – MF block valve, if applicable			
Any catalyst level changes in Rx, Regen, or Stripper			
Any new FCC unit alarms disables			
Any safety or environmental incidents			

Shift Handover Checklist
Outside Operator

Covers major points that can arise during the operations shift in ‘standby’ operation.

May be different for your specific site.

Provides a check for important information being shared during shift change.

Most sites will have to update all work permits at shift change, but depends on what time handover occurs.

When splitting shifts, it is important that ongoing maintenance activities are clearly communicated and understood.

Outside FCC Operator	Yes	No	Comments
Any new mechanical work started			
Any new work permits issues (hot or others)			
Changes in any control valve bypasses			
Any confined space work			
Any change in Rx – MF block valve, if applicable			
Any new contractors in FCC area doing work			
Any new equipment venting to atmosphere			
Any safety or environmental incidents			

Flavor
Simplified DCS Screen for Standby Operations

FCC Unit leaders prepare single DCS screen that allow operators to safely monitor a unit in standby operation.

Is designed for viewing only with no control functionality.

Focus is to reduce risk of air/hydrocarbon mixing.

This screen will be referred to as a "Simplified DCS Screen".

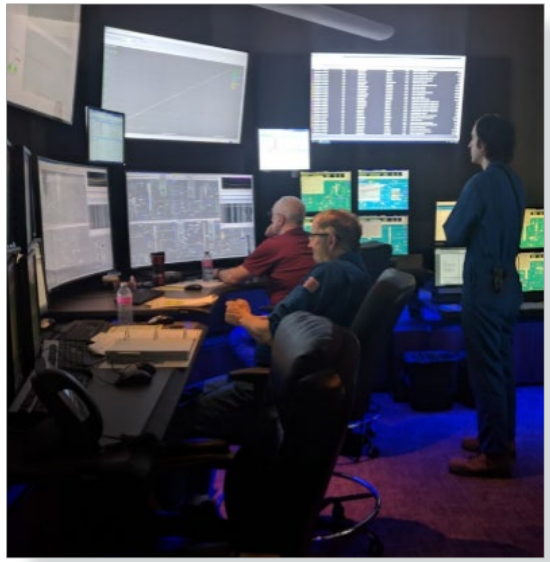
Used for quick, at-a-glance views of the Reactor/ Regenerator section of the FCC to ensure the Unit is in a safe position.

KPIs to include on the screen determined by the technical lead, in consultation with operations

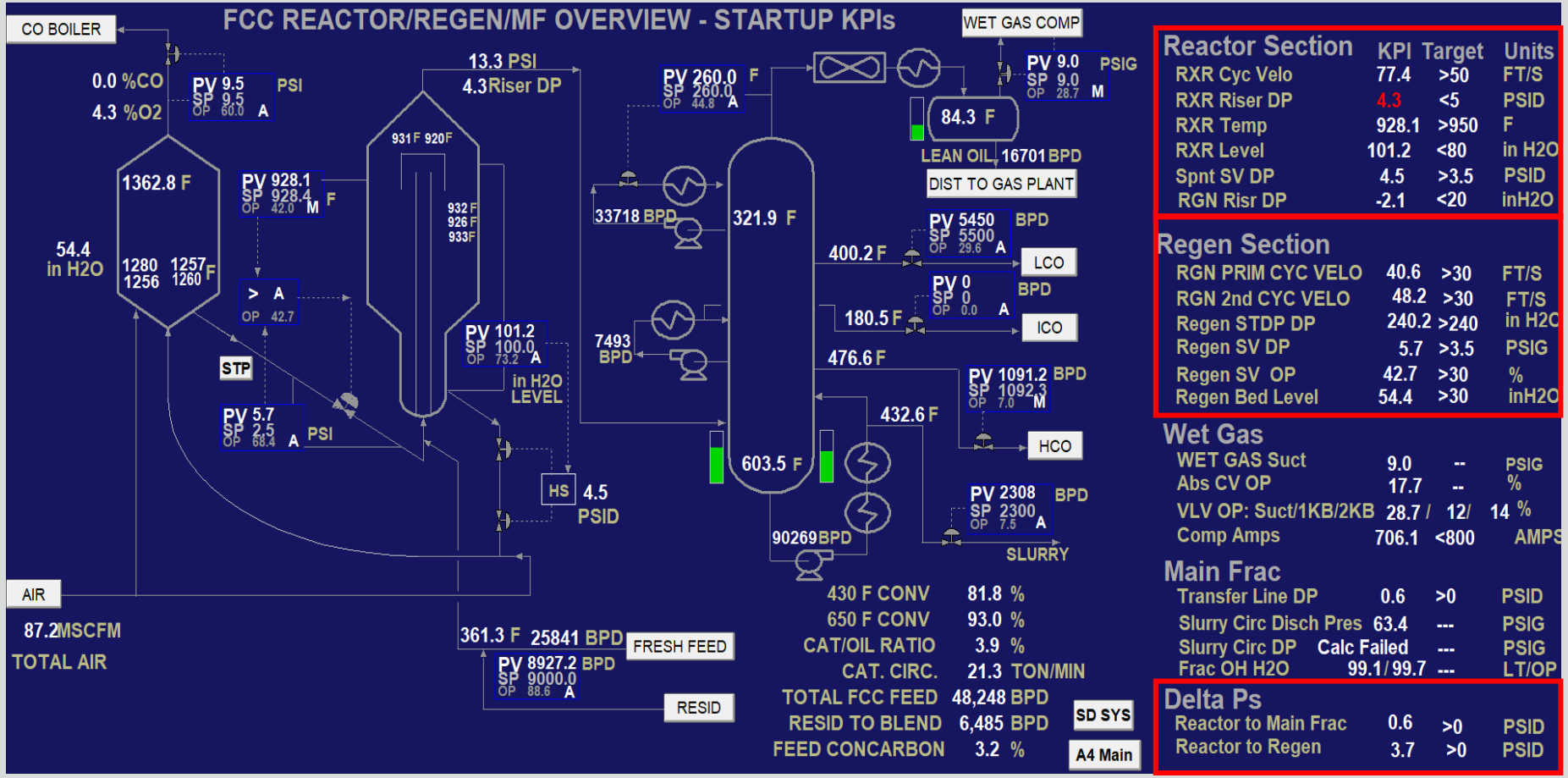
Keep it simple to maximize clarity

Leave graphic active on a large, highly visible monitor in the control room.

Process alarms and graphics designed for normal operation may not be helpful during shutdown, startup, and standby operation.



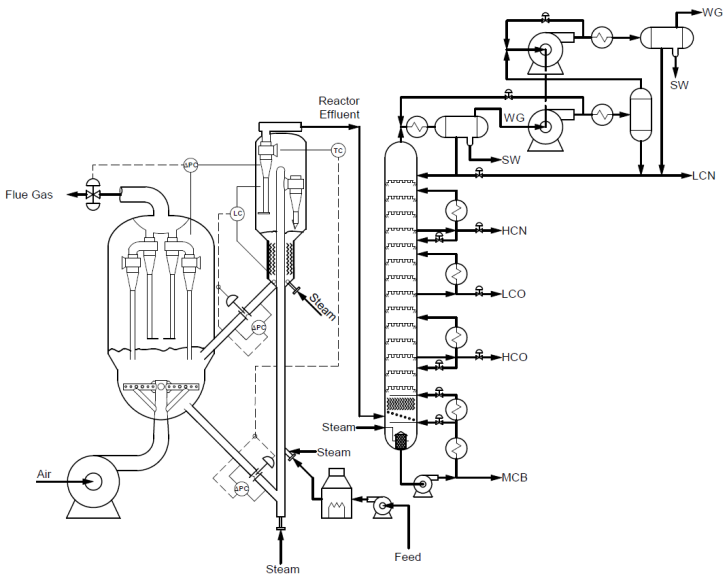
Simplified DCS Screen Example



Deep Dive
Standby Operation Monitoring

Purpose

Review and understand the key variables and challenges associated with monitoring these during standby operation.



Content

What are monitoring challenges during standby operation mode

What variables should we be looking at.

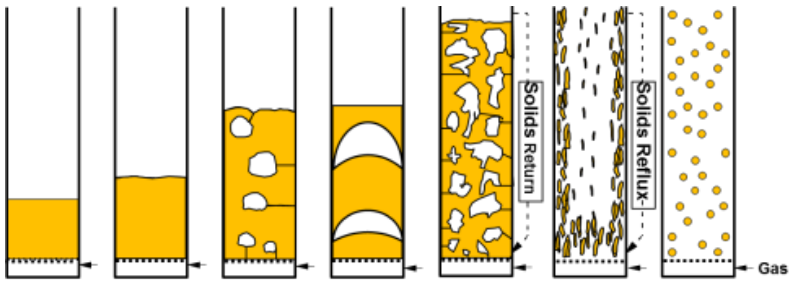
What does each variable mean? Understand the variable.

Standby Operation Monitoring

Monitoring challenges during standby operation

Level and ΔP instruments may not be reliable when in defluidized bed.

Instruments are designed for normal operational ranges and may not cover the expected values during standby operation.

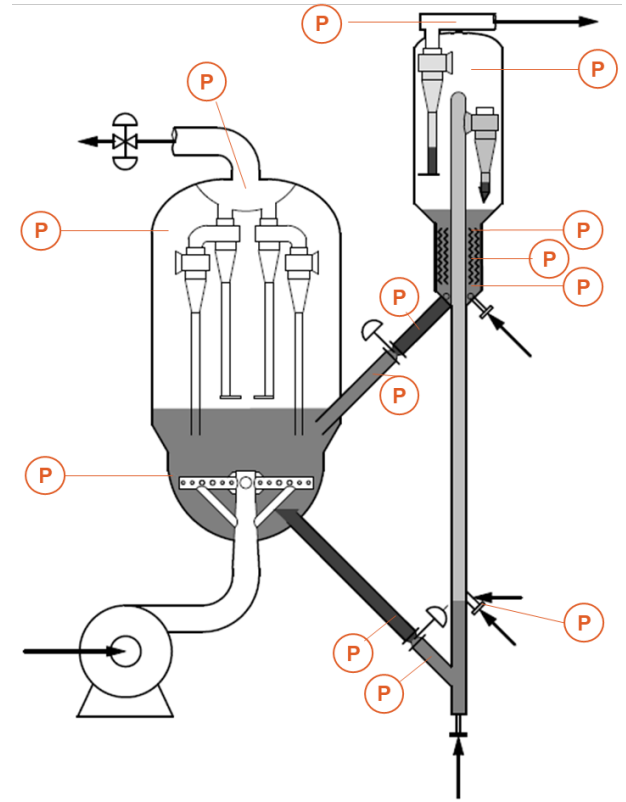


How to monitor unit for safe operation during this time

Ensure all instruments are within range to show required values.

Re-range instruments as needed (e.g. Rx/Rg ΔP & Rx temperature instruments)

Do not rely solely on one instrument. Look for multiple instruments that indicate the same findings. Example – Rx/Rgn Pressure transmitters and vessel DP.

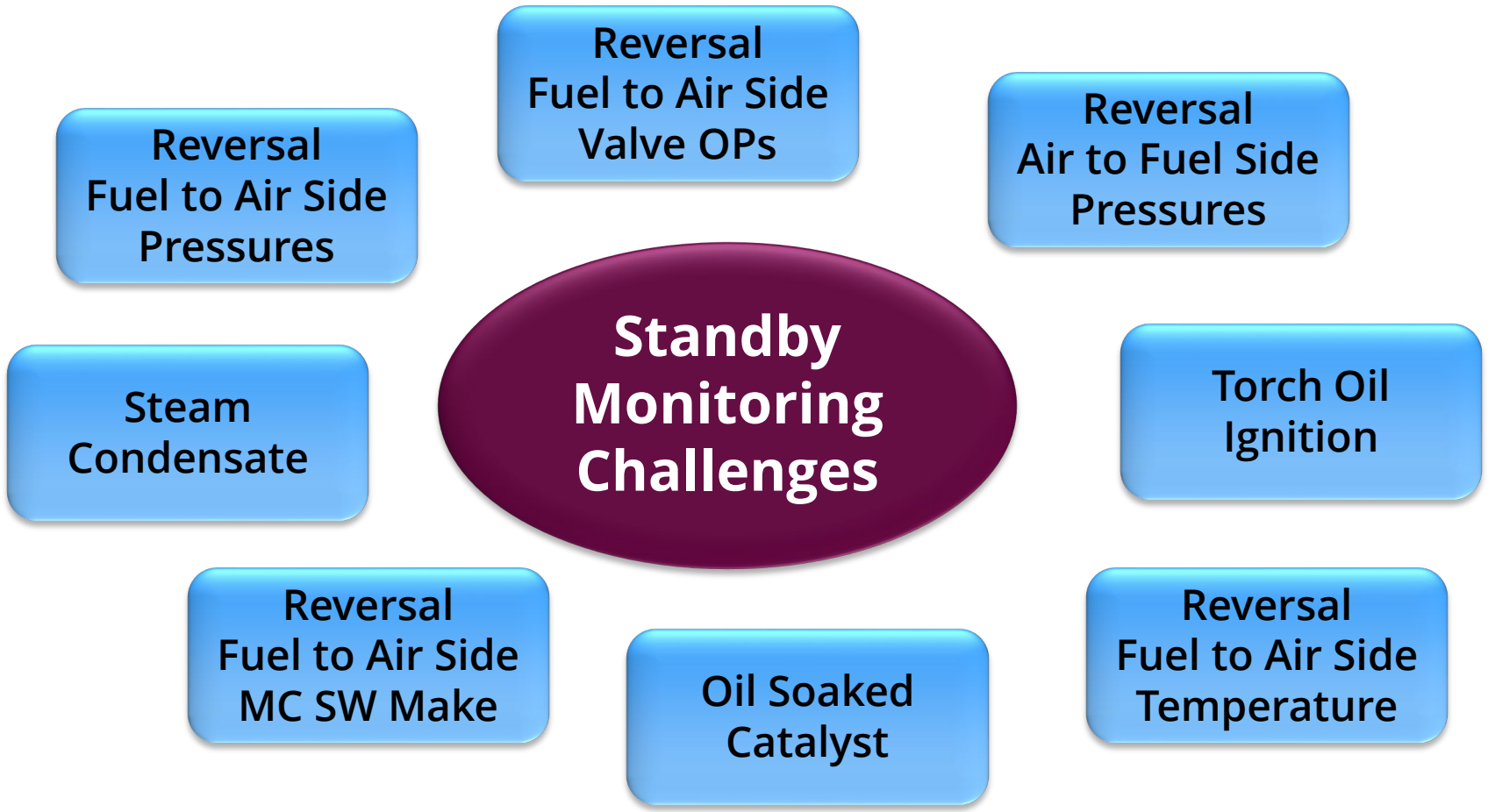


Standby Operation Key Variables

Key Variable	Comments
Rx/Rg ΔP	Reactor must be high pressure point of system (Rg P < Rx P > Main Frac P).
Slide Valve ΔPs	Slide Valve ΔPs may not be accurate due to low/zero catalyst flow, but should be monitored anyway for signs of potential reversal. Regen cat slide valve may be negative due to Rx P > Rg P.
Reactor Steam/Inert Gas Flow	Must keep sufficient flow of steam to Reactor to ensure steam flows forward to main fractionator.
Sour Water Make	Sour water production should match closely to steam injected into reactor. If it is low/zero, this indicates steam flow is going to regenerator and may not keep fuel gas from backflowing.
Reactor Temperatures	If temperature drops below saturated steam temperature, it could be an indication of fuel gas flowing from main fractionator to reactor. Note that many Rx TIs have a min range well above the operating temperatures during standby operation.
Main Frac Flare Valve Position	Should always have a small purge of gas to flare from the top of the main fractionator. If the valve closes, there may be fuel gas flowing backward toward the Reactor

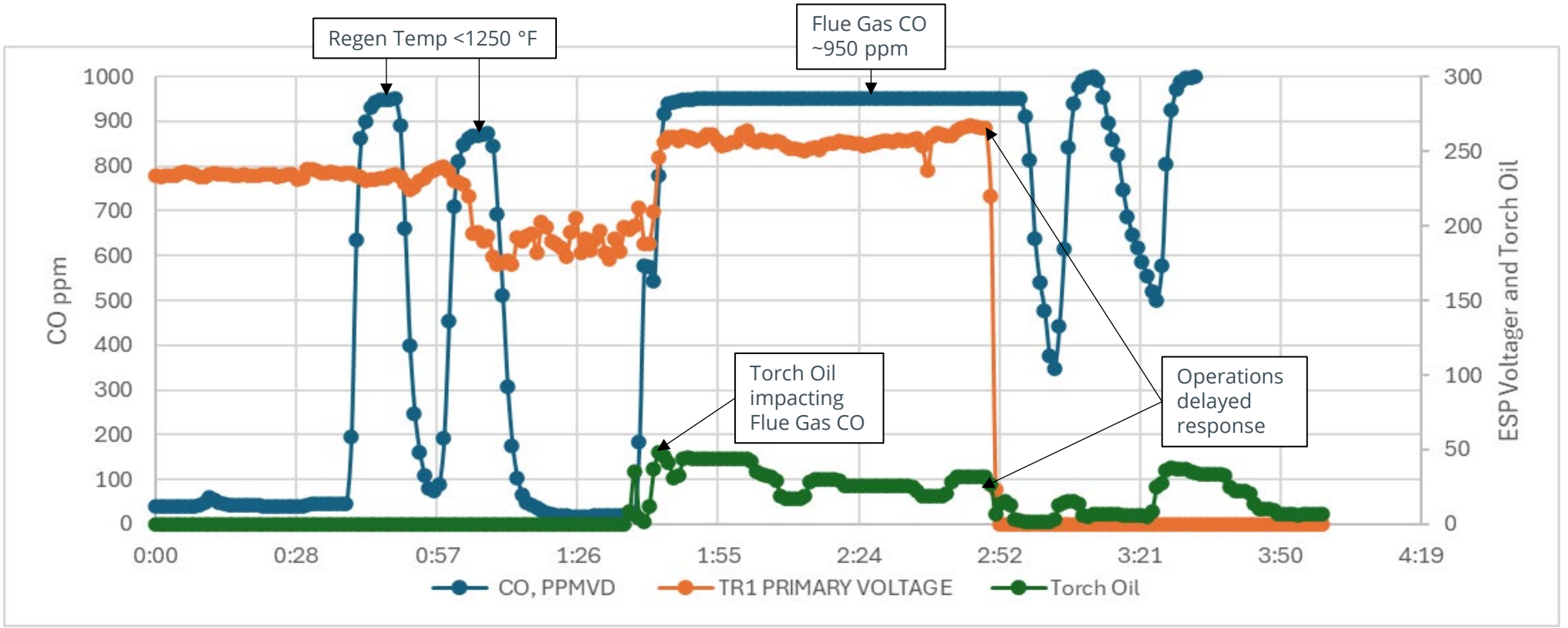
Standby Operations Monitoring Challenges

Summary



Standby Operation
Flue Gas Analyzer Flat Line

BACK



Feed Upset

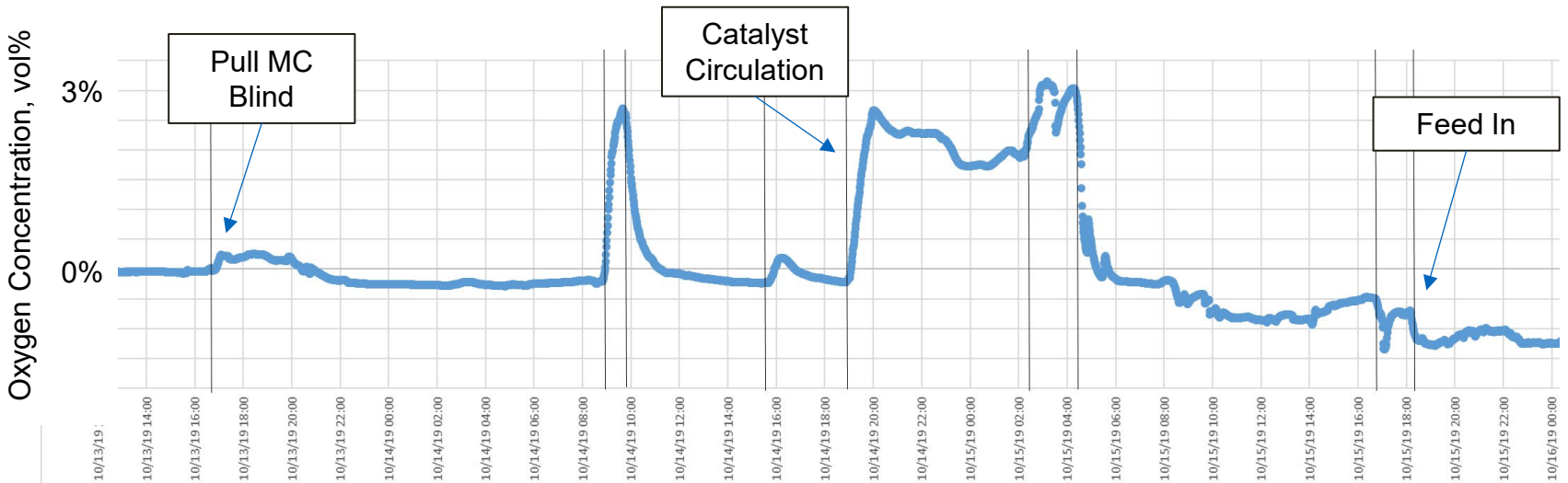
- CO spiked up when regenerator dense bed temperature fell below 1250°F.
- Torch oil resulted in high flue gas CO < 1,000 ppm
- Board operator noticed CO was not changing and deenergized the ESP.

Lesson Learned - Some instruments will record last reasonable reading and flatline. Set guidelines below the top of scale

Standby Operation Main Frac O2

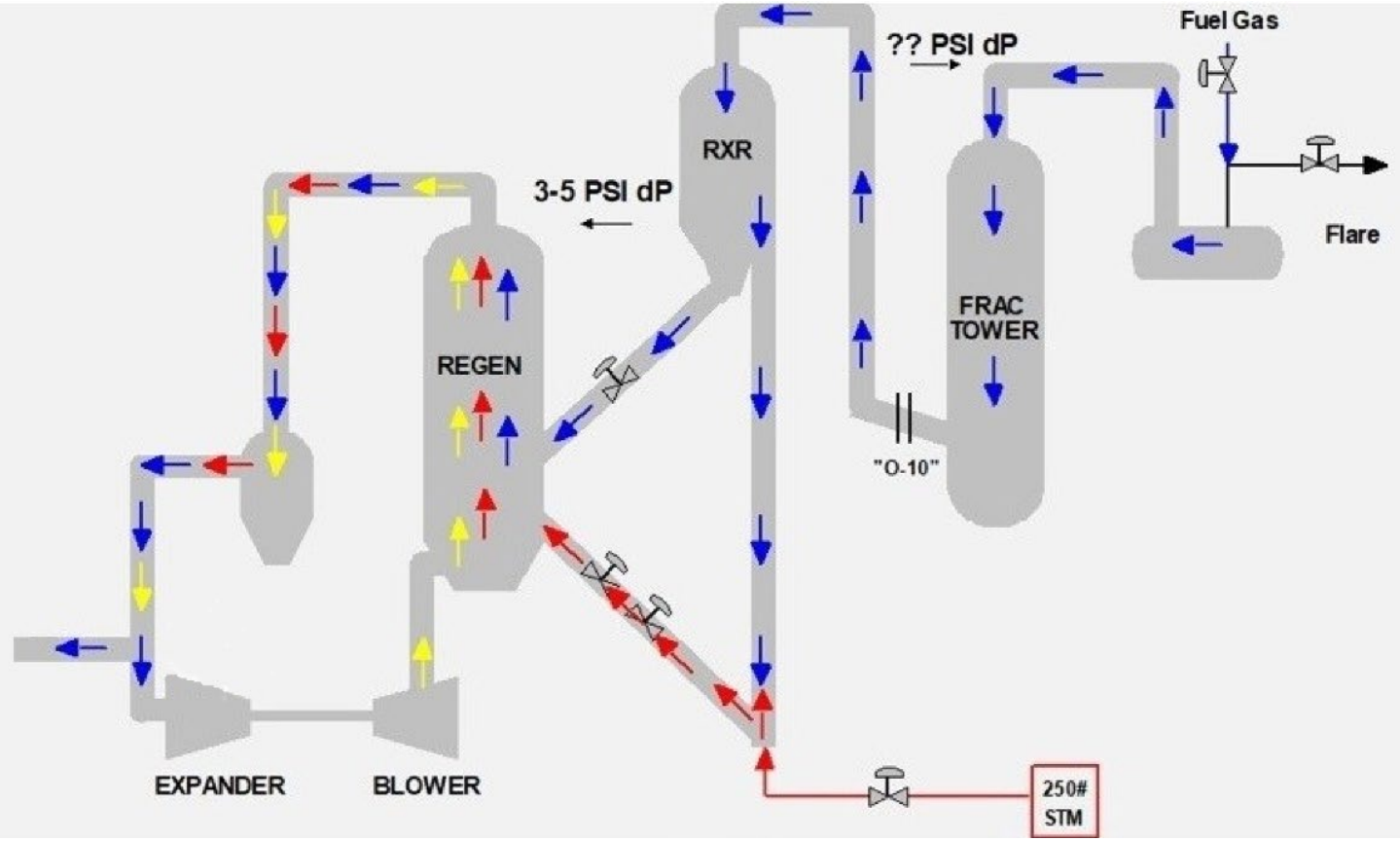
BACK

- During ‘steam circulation’ phase of startup/shutdown oxygen can reach high concentrations in Fractionator overhead downstream of condensers
- Oxygen concentration can reach high enough levels to be a threat for ignition with pyrophoric material – accidents have happened in industry
- Continuous purging to flare via inert (nitrogen or natural gas) is a mitigation for accumulating oxygen
- Monitoring of oxygen content via sample or analyzer is recommended
- Maximum oxygen content is generally accepted as 2 vol%



Standby Operation Reversal – Fuel to Air Side

BACK



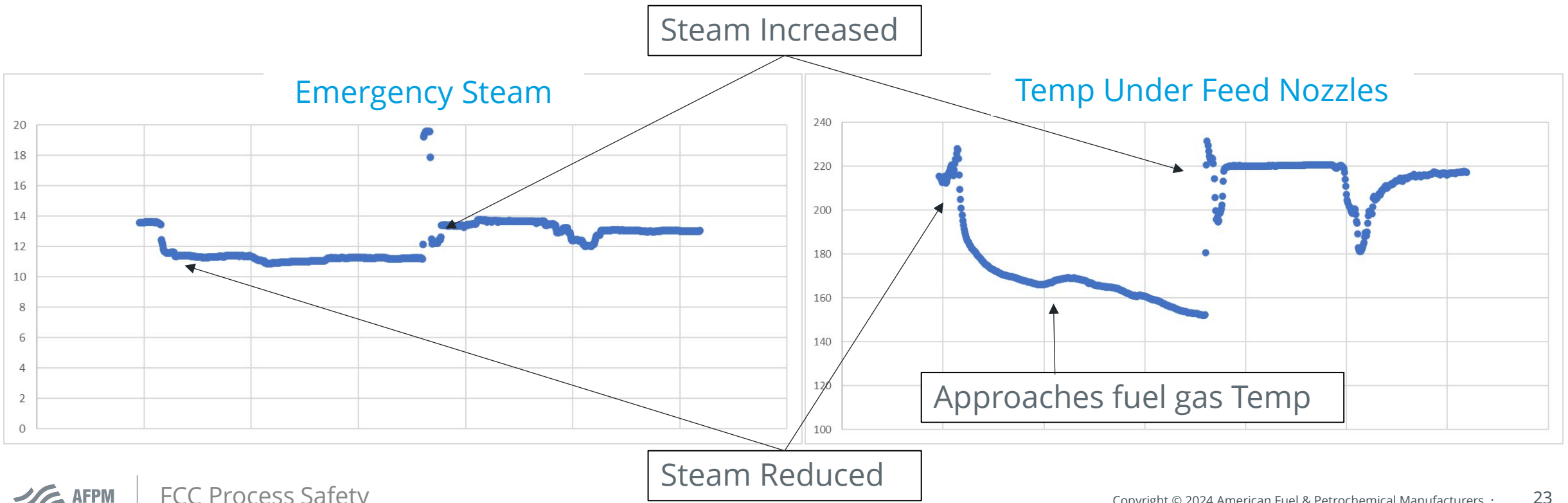
Reactor Pressure must stay higher than the Regen and Main Column

- Many times, the Reactor and Main Column pressures are very similar. What else can be monitored to prevent a fuel to air side reversal?

Standby Operation Reversal – Fuel to Air Side

BACK

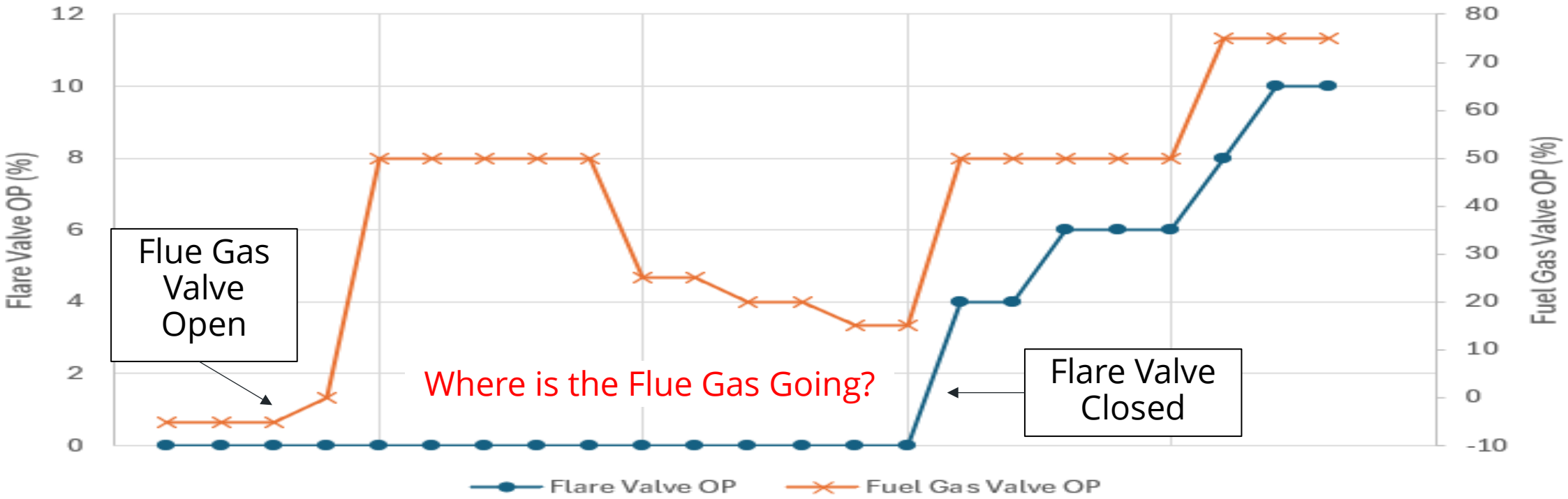
Monitor the temperatures in the riser, beneath the feed distributors



Standby Operation Reversal – Fuel to Air Side

BACK

Monitor Fuel Gas Valve and Flare Valve

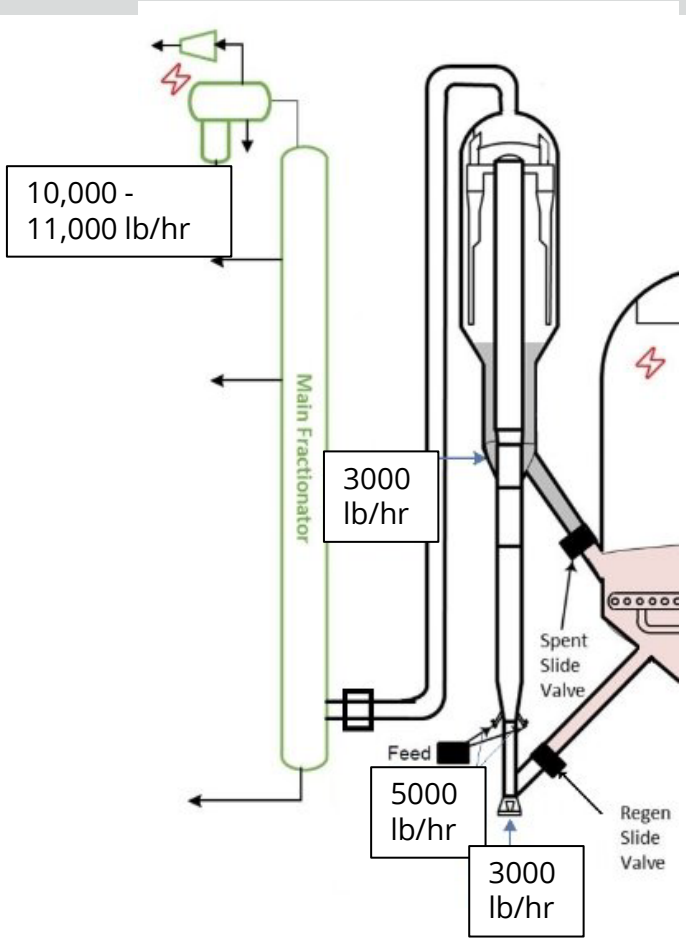


Standby Operation
Main Frac SW Make Example

BACK

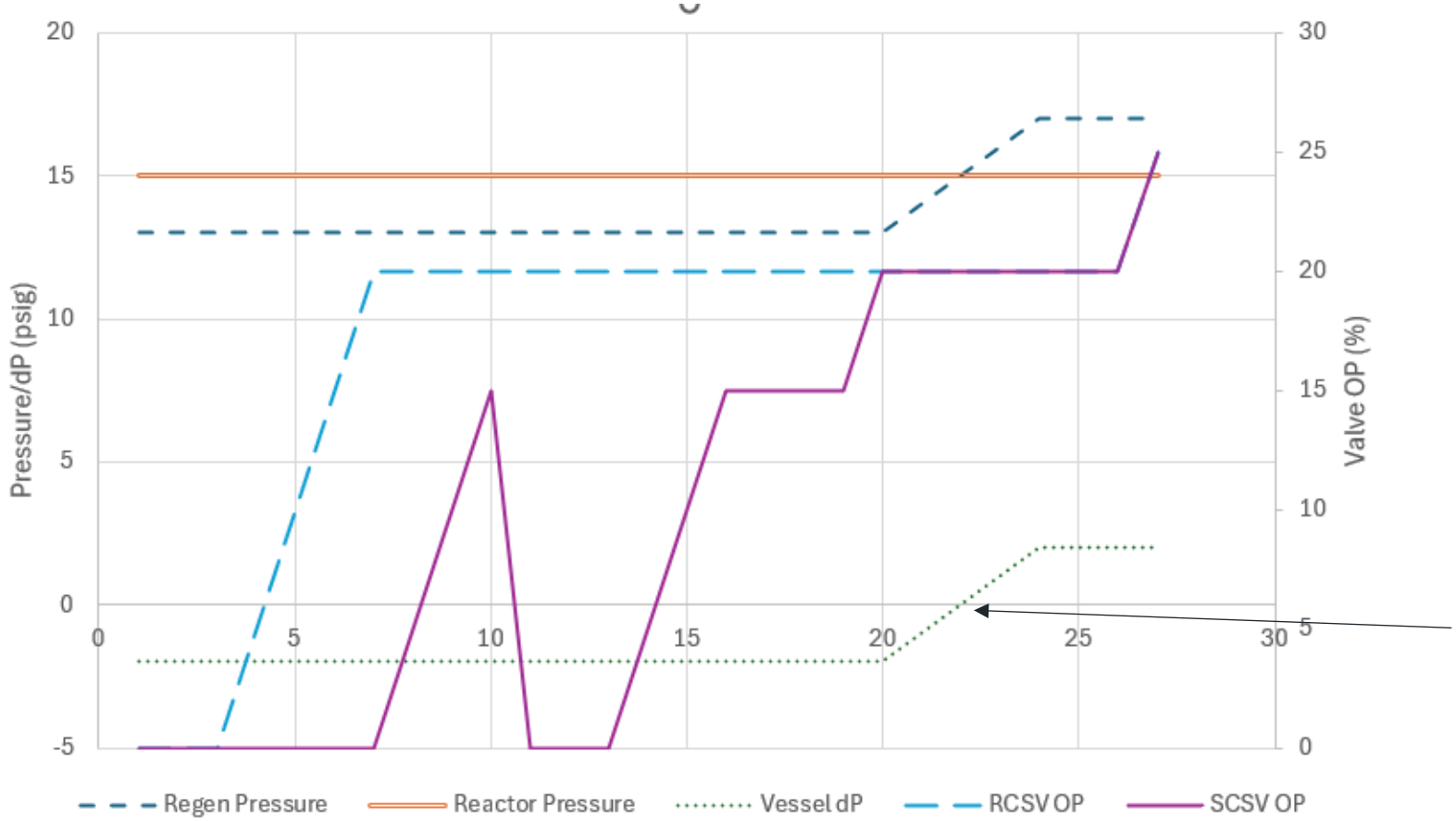
Monitor the Sour Water Make vs the Reactor Steam Rates

- Delta is going to the Regenerator
- Increases overtime indicate larger flow path across SV for gas to flow
- Lower recovery indicates importance of maintaining pressure balance and susceptibility to gas reversal if steam rates are lowered



Standby Operation Reversal – Air to Fuel Side

BACK



Ensure Reactor is higher pressure than Regenerator

- RECAP: Gas flows from High to Low pressure
- Reactor at higher pressure will keep air on the Regenerator side

Vessel dP only goes positive after catalyst circulation is well established.

Standby Operation Steam Condensate

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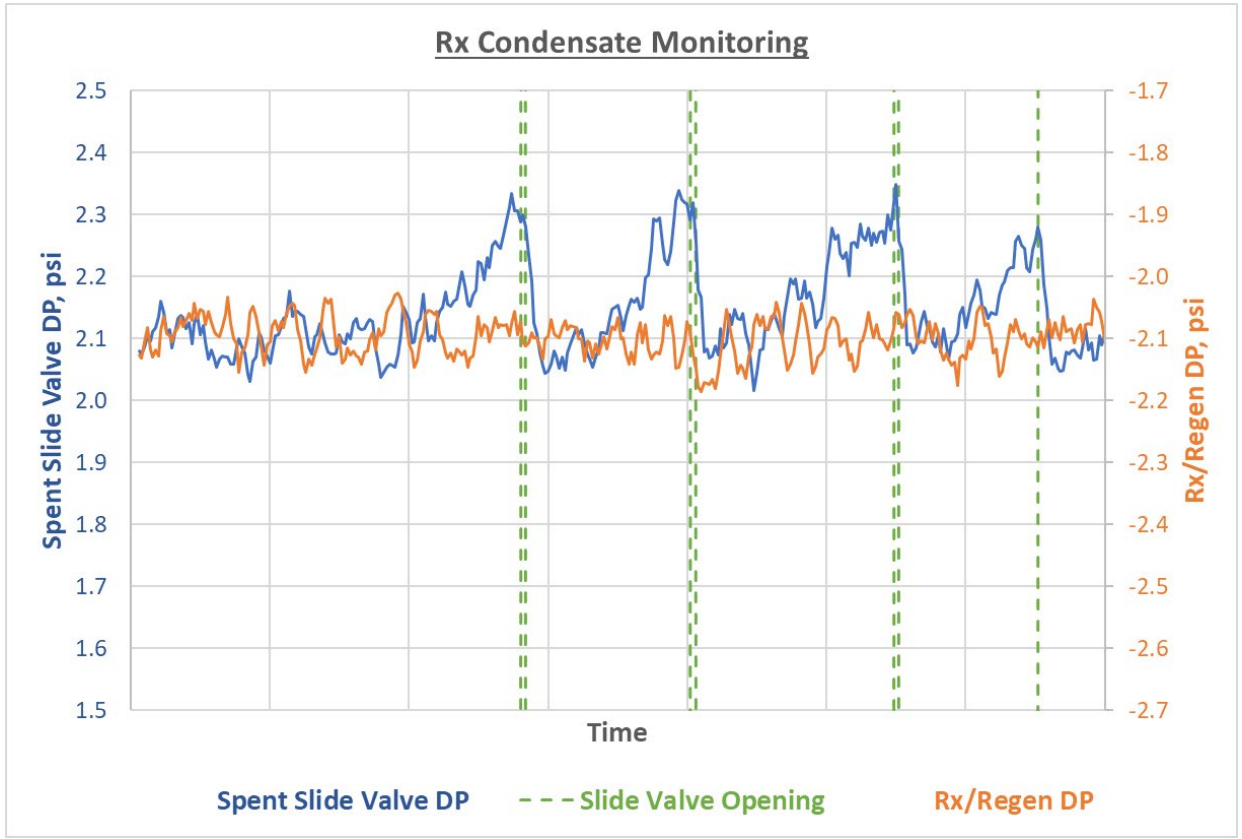


Condensate Monitoring

- With Reactor empty, Spent SV dP should ~mirror the Rx/Regen dP
- While steaming out the Reactor, significant amount of condensate can accumulate on the SV, as seen with an increase in SV dP.
- Left alone, this condensate can lead to pressure balance upsets, wet catalyst which can inhibit catalyst circulation, and Regenerator temperature upsets

Standby Operation
Oil Soaked Catalyst Example

BACK

Variables

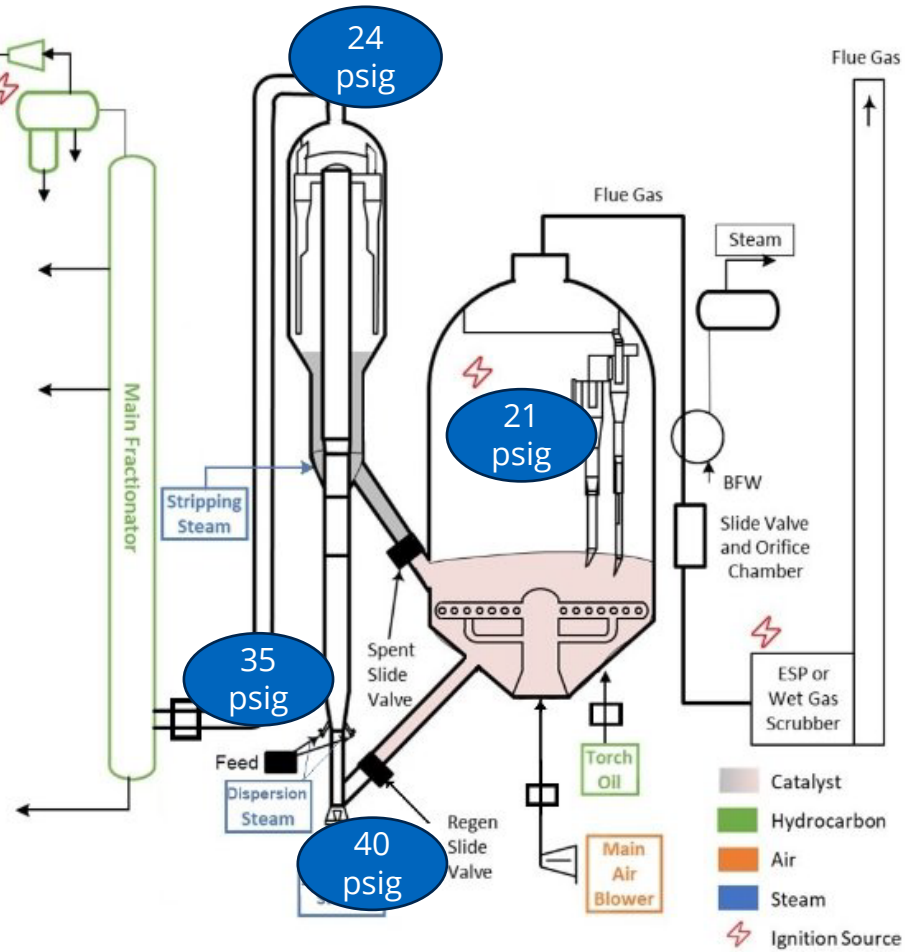
Pressure at the feed nozzles – 35 psig
Pressure at the top of the Reactor – 24 psig
Regenerator pressure – 21 psig
Pressure under the Regen Slide Valve – 40 psig

Why? What Happened?

Opened Regen slide valve, no temperature increase. Why?

Riser full of oil. What Happened?

Leak by of the SIS valve. Riser had to be drained and pressures equalized at 24 psig before catalyst circulation was re-attempted.



Standby Operation
Torch Oil Ignition

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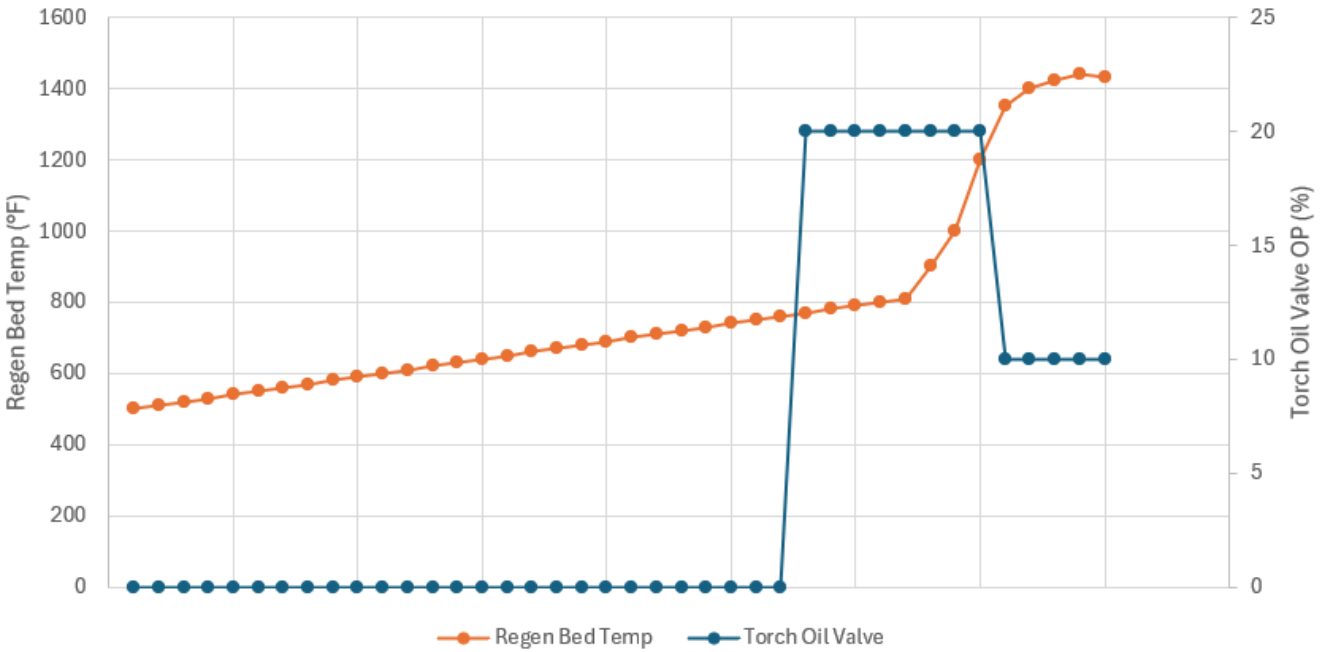
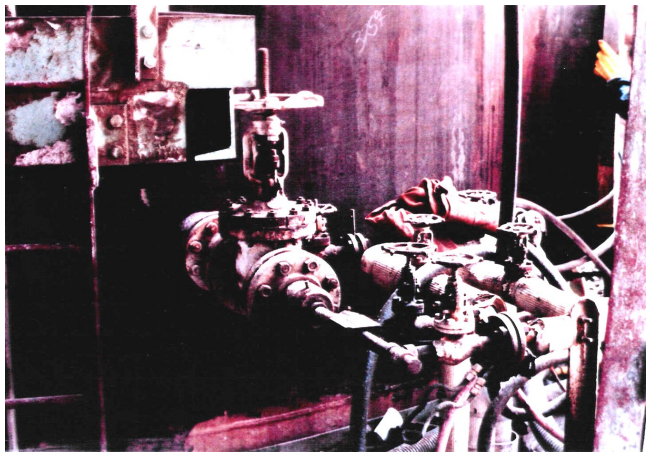


Unit Monitoring for safe Torch Oil use

- Understand your torch oil quality
- Ensure you have sufficient catalyst level
- Watch temperatures for ignition
- Generally, ESP is shutdown when torch oil is in use



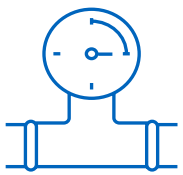
Standby Operation Monitoring
Summary

BACK

Monitoring during standby operations offers many challenges. There are many examples from around the industry in which improper monitoring has led to serious consequences or could have under the right conditions.

When in standby, always remember:

Standby is an operating mode



The unit is not in its normal operating envelope. Process variables such as pressure, temperature, flow or composition may be different than normal operations. Not all scenarios can be anticipated.

The unit may also be in a transient state as it shifts from one operating mode to another.

Exercise
Simplified DCS Screens

Fun with dry eraser markers!