Air and Hydrocarbon

Learning Objectives

Define good practices for the prevention of explosive mixture formation that could result from various causes in the FCC.

Flavor · Practice Shares

Slide Valve Online Erosion Monitoring

Slide Valve Purge for Safe and Reliable Operation

Safe ESP Operation

Safe Direct Fired Heater Operation

Safe Torch Oil Operations

Deep Dive · Torch Oil

Exercise · Procedures

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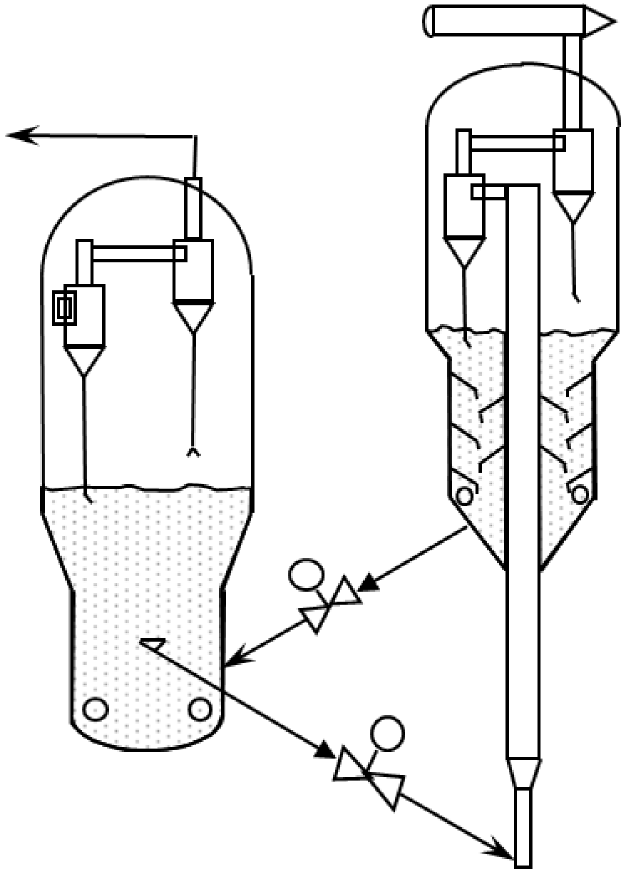
Air and Hydrocarbon
Review Hazards of Air & Hydrocarbon

Regenerator Fire Triangle

- ✓ Oxygen –Main Air Blower or ESP/CO Boiler
- ✓ Ignition Source – Hot surfaces, ESP Sparks

Risks

- Hydrocarbon from main fractionator
- Unburned gas from the air heater
- Unburned Torch Oil



Reactor Fire Triangle

- ✓ Fuel - Hydrocarbon from the process
- ✓ Ignition Source - Pyrophoric Scale

Risks

- Oxygen from the Regenerator

Slide Valve Online Erosion Monitoring

Associated Risks

Air ingress to the Reactor

Hydrocarbon backflow to the regenerator

Source

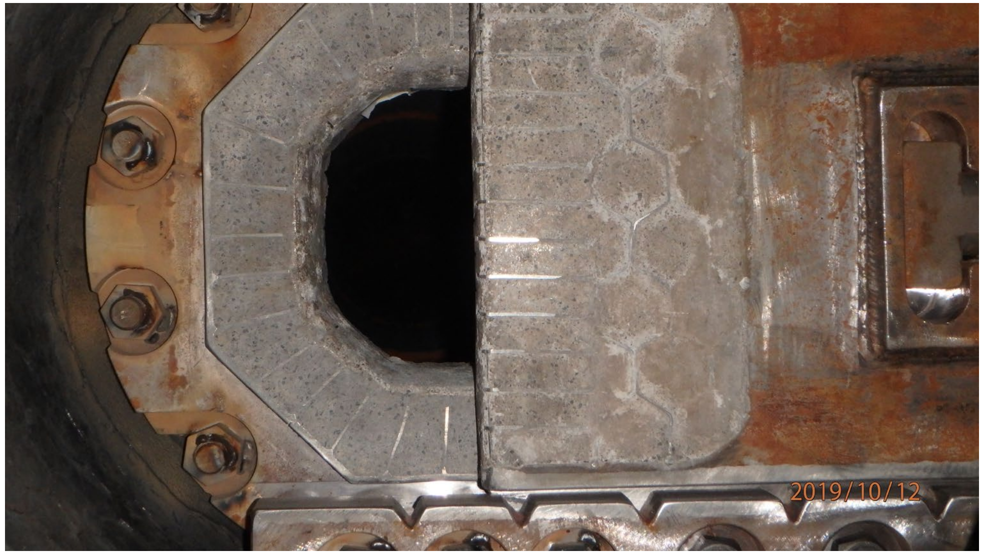
Unexpected loss of catalyst level followed by gas/air flow resulting from eroded valve internals

Compromised slide valves were contributing factors in some recent high consequence FCC incidents, in non-routine operations.

Practice Share Objectives

Review methods for monitoring slide valve integrity

- Early identification of slide valve damage
- Raise awareness about potential for gas leakage in standby
- Enable planning: procedure mods, T/A repairs, etc.



Slide Valve in Good Condition after Turnaround

Slide Valve Online Erosion Monitoring (cont'd)

Does the Orifice Coefficient make sense?

$$C_v = \frac{CCR}{\sqrt{A * 2 * \Delta P * p}}$$

Where:

C_v = Orifice Coefficient

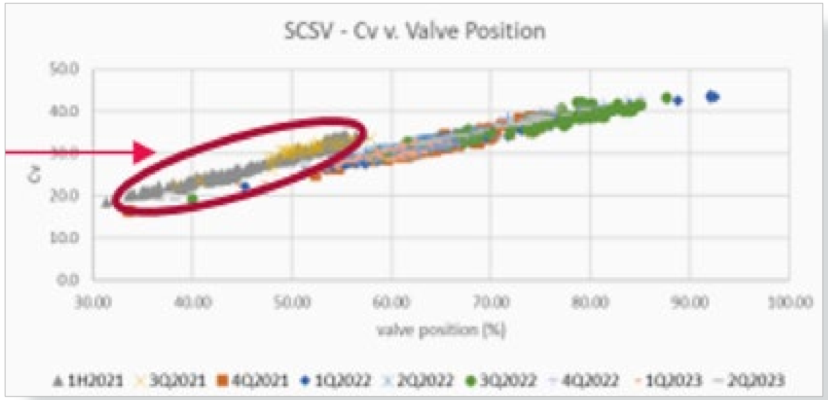
CCR = Catalyst Circulation Rate

A = Exposed Orifice Area

ΔP = valve pressure drop

p = catalyst flowing density through valve

Plotting C_v vs. Valve Position



Husky Superior 2018 Incident:
SCSV Erosion

CSB Investigation Report, Figure 34

Plot should not change slope or step change

Slide Valve Purge for Safe and Reliable Operation

[Associated Risks]

Air ingress to the Reactor

Hydrocarbon backflow to the regenerator

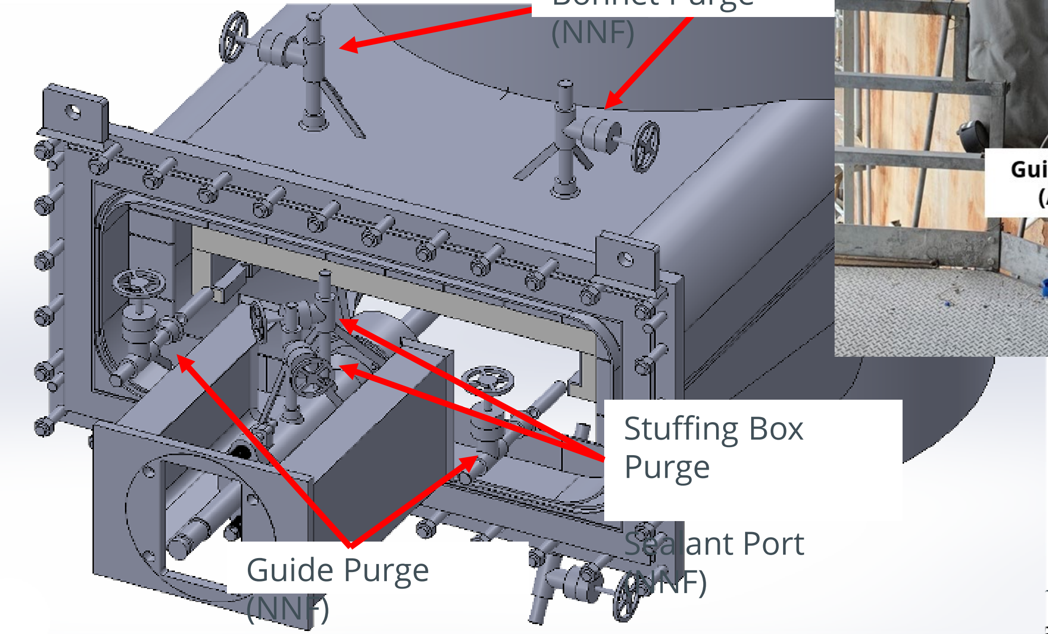
[Source]

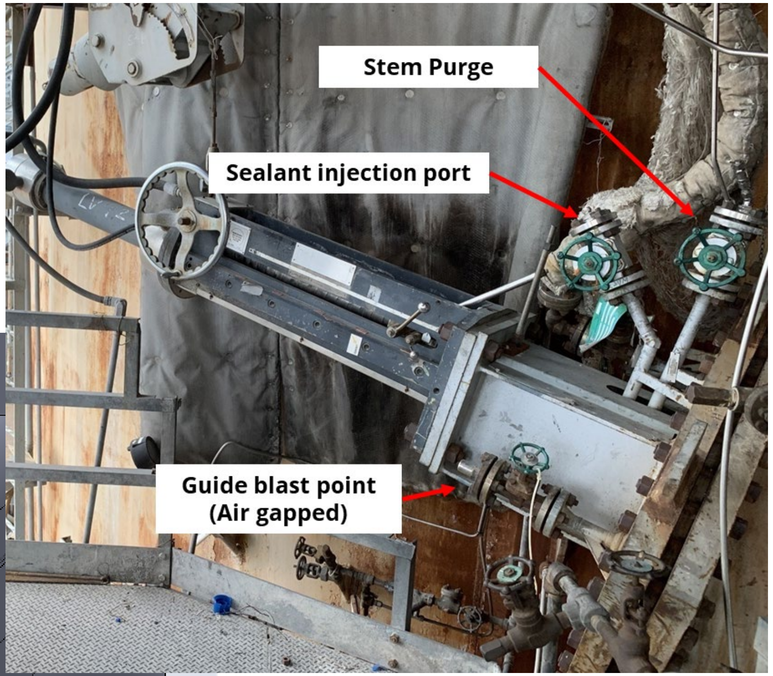
Compromised valves may not move when needed or close in case of a shutdown.

FCC valves have numerous purges on them – some are required during normal operation, some are not.

[Practice Share Objectives]

Share slide and plug valve purging practice that are recommended by equipment manufacturers and used by refiners.





Slide Valve Purge for Safe and Reliable Operation (cont'd)

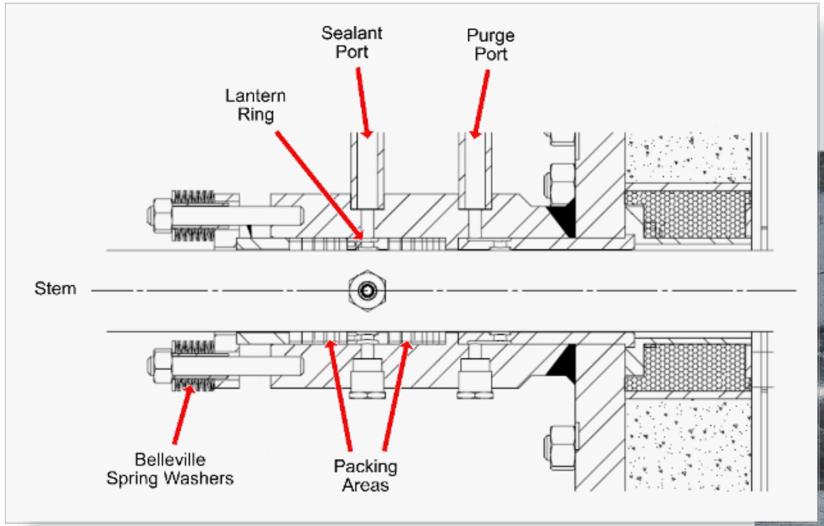
Stuffing Box Purge

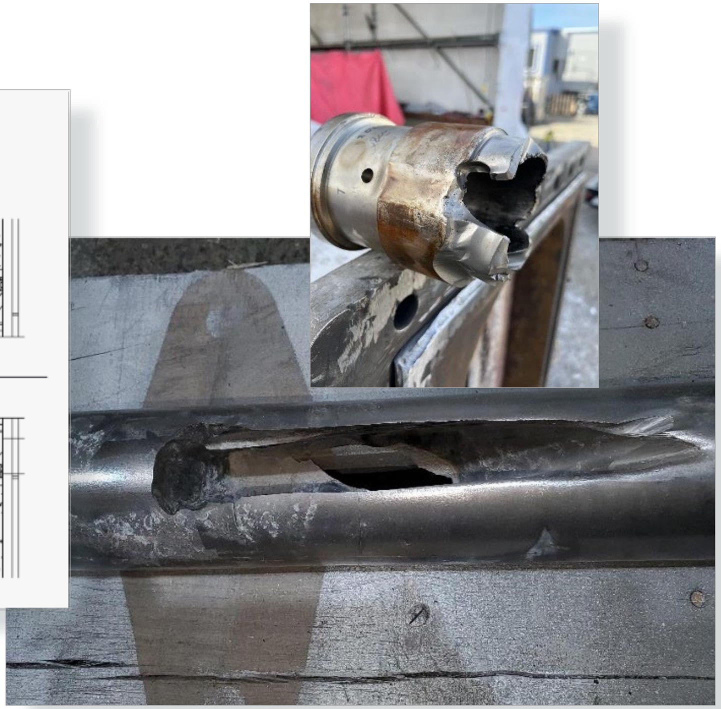
Ideal **pressure** entering stuffing box to be between 5 to 10 psi above process pressure. Consult original equipment manufacture.

Correct **Restriction Orifice** size to achieve pressure needed.

Insufficient flow will cause catalyst to build up within the stuffing box. Can lead to catalyst loss of containment out of the stuffing box

Excessive flow will erode the stem, packing, and internals.

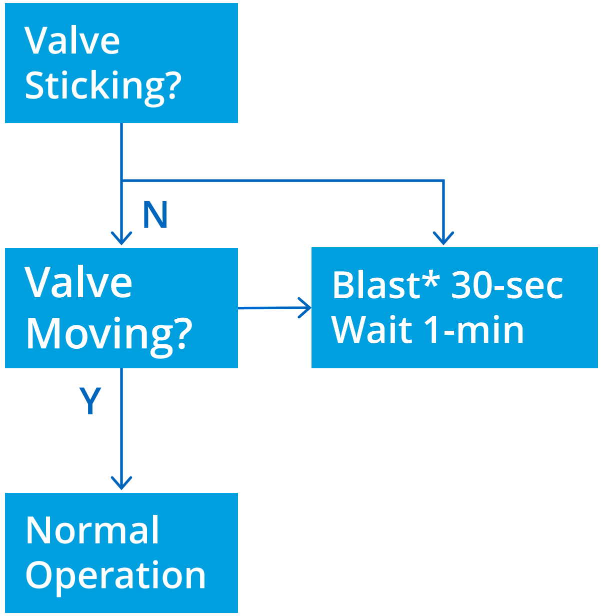




Damage caused by incorrect stuffing box purging

Slide Valve Purge for Safe and Reliable Operation (cont'd)

How to use the Emergency Guide Purge



A block valve may leak when guide purge lines are hard-piped, damaging guides and disc.

Use Flexible Hoses when needed, follow the blasting* procedure.

Damage consistent with continuous use of guide purge

* Blasting refers to steam or nitrogen purge

Safe ESP Operation

Associated Risks

Risk of explosion, personal injury or fatality

Source

When energized, the ESP provides an ignition source

- Fuel sources: uncombusted torch oil, DFAH fuel gas, CO boiler aux gas, hydrocarbon backflow from frac
- O2 sources: regen, CO boiler, ESP penthouse purge

An informal industry survey conducted in the early 2000s indicated several operating ESPs have had **explosion incidents** within their lifetime.

The energized ESP was the ignition source for the Torrance FCC incident in 2015.

Practice Share Objectives

Provide commonly used safeguards for preventing ESP-related process safety incidents.

- Procedures, monitoring, SIS's

Torrance 2015 Incident: ESP Damage
CSB Investigation Report, Figure 18

Safe Direct Fired Heater Operations

Associated Risks

Accumulation of hydrocarbons in the Regenerator or flue gas system

Loss of primary containment

Source

Failure to ignite / Loss of flame

Incomplete combustion

Excessive heat output leading to mechanical damage/loss of containment.

Practice Share Objectives

Minimize the risks associated with operating the FCC regenerator direct fired air heater (DFAH).

Highlight the key items for safe air heater operations in start up procedures and operator training to reduce the associated process safety risks.

Safe Direct Fired Heater Operations

Common DFAH Risk Mitigations
- Burner management system (BMS) – e.g. flame scanners
- ESD interlocks – low air flow, low fuel gas pressure/flow, high outlet temperature, etc.
- Procedures and Operator monitoring

Often times risks are downplayed as the heater is used only during startup. Heaters that operate continuously likely need additional layers of protection.

Flame Out resulting in uncontrolled combustion

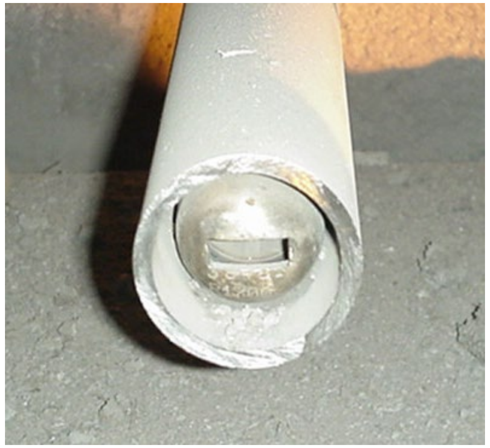
Safe Torch Oil Operations

Associated Risks

Explosion in flue gas system or release of hydrocarbon plume

Source

Improper use of torch oil (lack of combustion)



Practice Share Objectives

Minimize the risks associated with using torch oil in the FCC regenerator.

- Describe main risk areas for torch oil use
- Highlight the key FCC procedural items for safe torch oil use (start up, shut down, and emergency)
- Outline focus areas to improve frontline operator training
- Share monitoring, maintenance, procedural and training barriers used by refiners that can be used to mitigate these risks.

Deep Dive
Keys to Safe Torch Oil Use

Introduction

There have been incidents across the industry where Torch Oil was admitted to the regenerator in a way that compromised the safety of the unit.

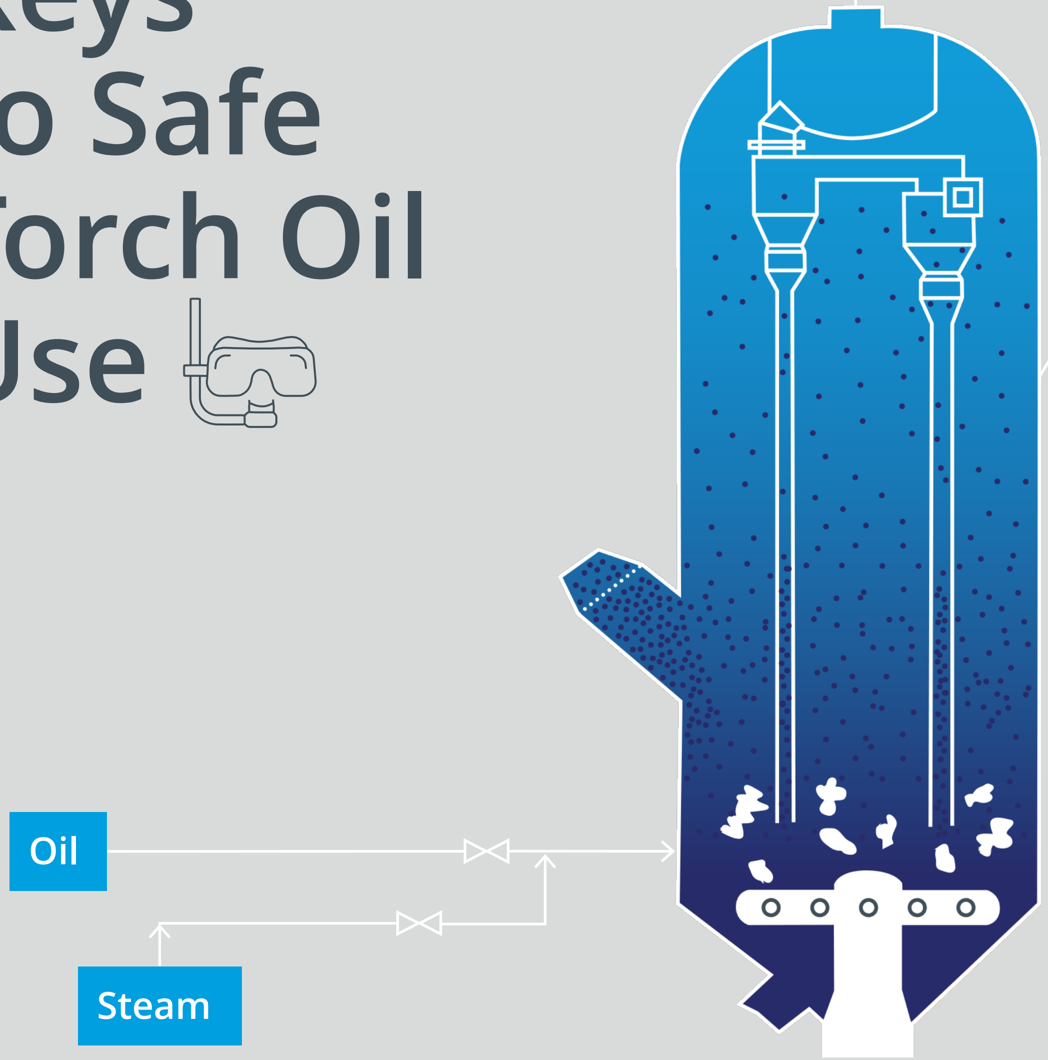
Two common factors among these incidents were

The desire to save the unit.

A lack of understanding of the requirements for introducing torch oil to the regenerator.

The purpose of this module is to provide a simple set of monitoring points to check prior to using torch oil in the FCC.

Keys to Safe Torch Oil Use



1. Excess O_2

O_2 is needed for combustion. Insufficient air can result in un-combusted torch oil to downstream equipment

2. Temperature

Temperature needs to be high enough to ignite the oil. (>800°F)

Temperature increases should be observed with flow

3. Bed Level or Density

There needs to be enough catalyst at the Torch Oil nozzle to absorb the heat and assure burning.

4. Composition

Light oils vaporize too quickly to burn in the bed. Avoid alternative torch oil sources unless the boiling range is correct.

Keys to Safe Torch Oil Use

Summary

Torch Oil Scenarios

- Excess O_2 Scenario #1
- Excess O_2 Scenario #2
- Excess O_2 Scenario #3
- Excess O2 Scenario #4
- Composition
- Temperature
- Level Or Density

Keys to Safe Torch Oil Use

1. Excess O_2, Scenario #1

BACK

ESP Deflagration

Scenario description:

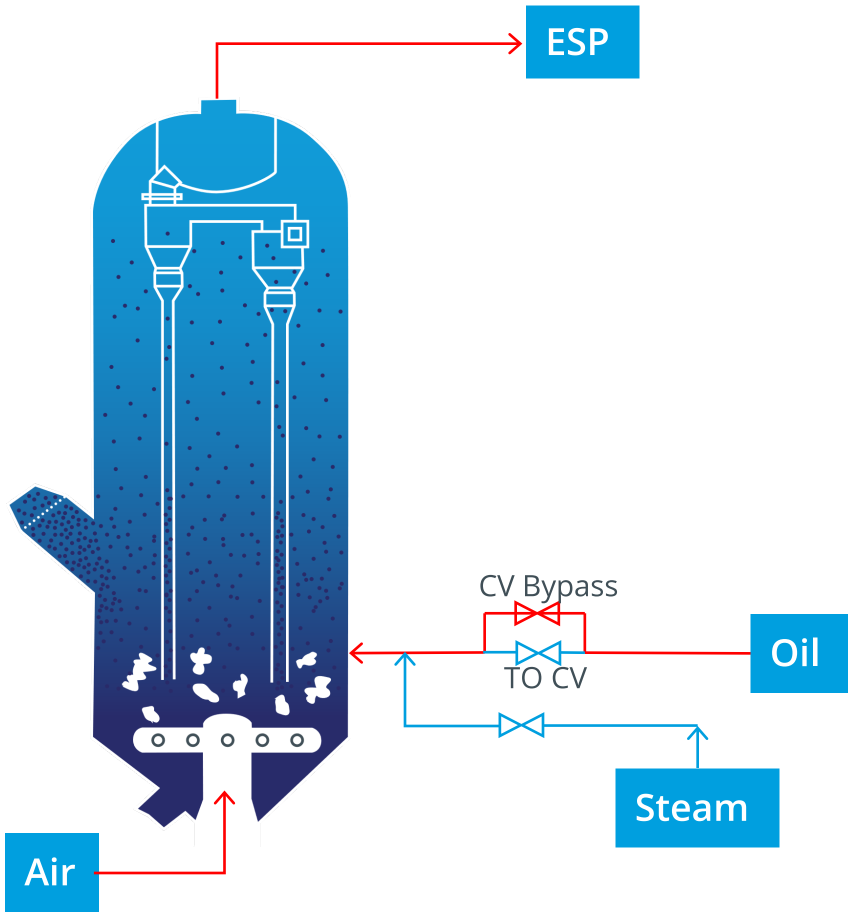
FCC shutdown, blower taken to min governor due to steam shortage

Attempt made to introduce torch oil to the regenerator:

- Site wanted to keep regen hot for quick restart
- Safety interlock system did not allow torch oil CV to open

Control valve bypass manually opened to introduce TO, defeating SIS

- Insufficient air flow to combust all oil
- Vaporized, un-combusted oil flowed to ESP, which was energized
- Explosive oil/air mixture ignited on ESP.



Keys to Safe Torch Oil Use

1. Excess O_2, Scenario #2

BACK

Flammable Mixture Ignites in CO Boiler

Scenario description:

Following unplanned SD, TO introduced with insufficient air

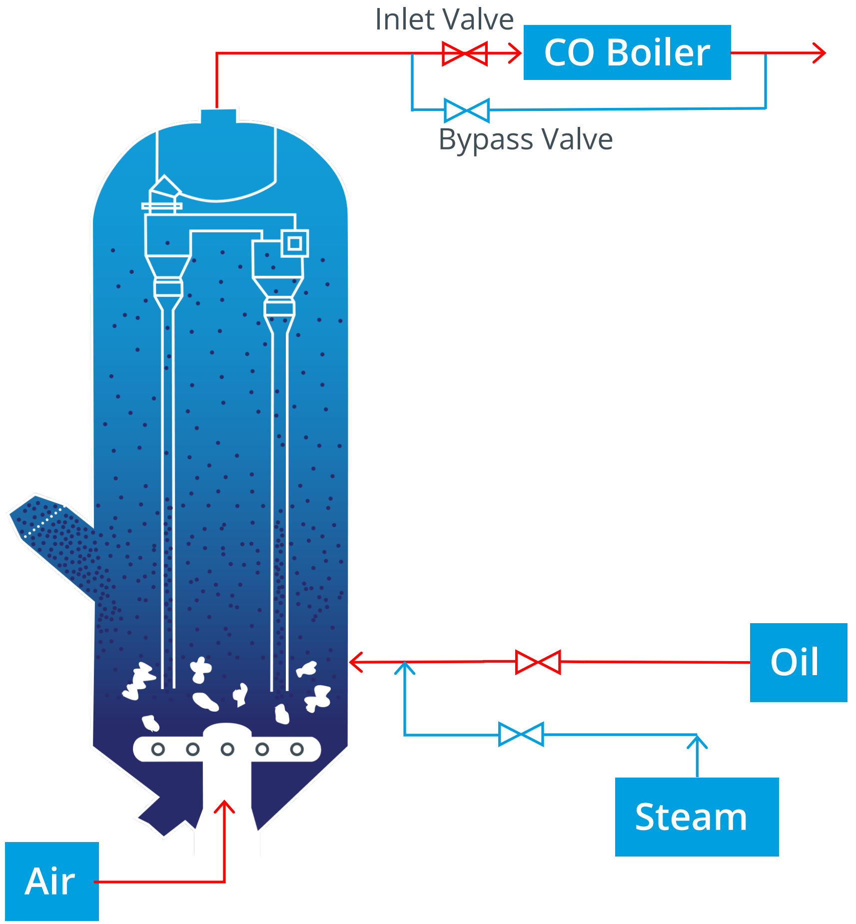
- Light-off confirmed by bed TI's, but O2 quickly dropped to 0, CO increased
- TO continued for several hours
- Startup aborted and TO removed, but significant oil accumulated on regen bed

Regen heat-up later resumed with DFAH

- The accumulated torch oil vaporized creating an explosive air/HC flue gas mixture

Began opening CO boiler inlet valve to feed flue gas:

- Boiler flame presented an ignition source for explosive air/HC mixture
- Flame propagated upstream of the boiler
- Caused significant damage to U/S equipment (expander, TSS, expansion joints)



Keys to Safe Torch Oil Use

2. Temperature

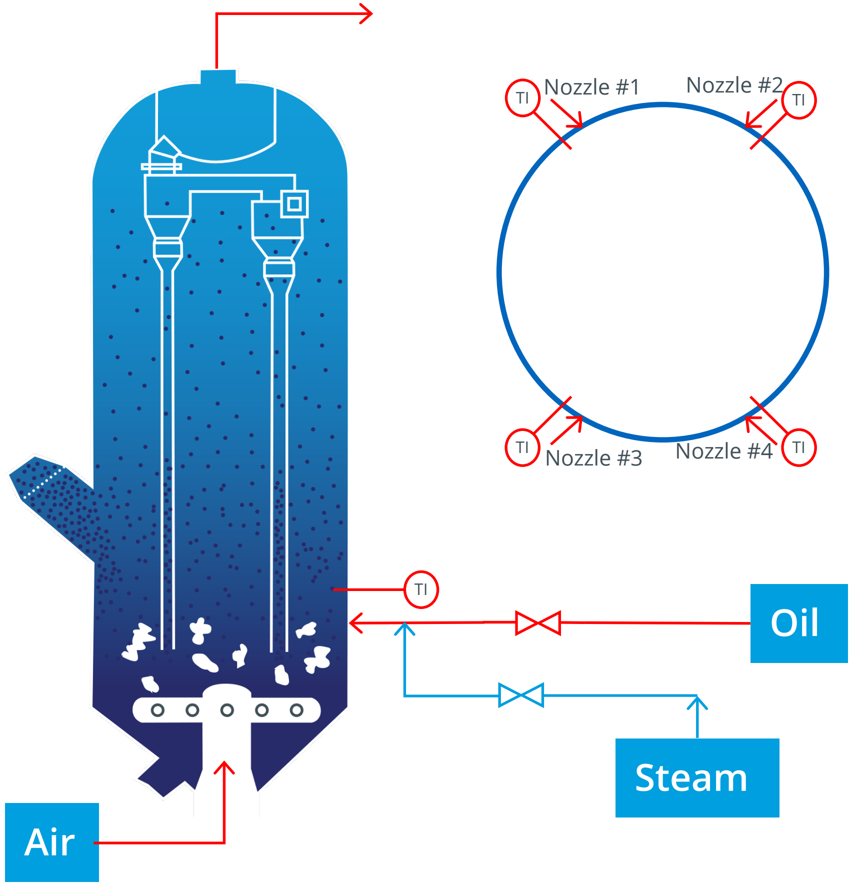
BACK

The regenerator temperature needs to be high enough for torch oil ignition.

- Typically 750°F – 800°F Minimum Temperature

When the torch oil is introduced, watch the TIs close to the injection points for an increase within 2-3 minutes.

- If not, the torch oil is likely not burning, which could form an explosive mixture.
- Close the valve and review the situation before raising the flow.



Keys to Safe Torch Oil Use

2. Temperature, Scenario #1

BACK

Coke Build-up & Temp Excursion

Scenario description:

FCC shutdown an uncontrolled manner

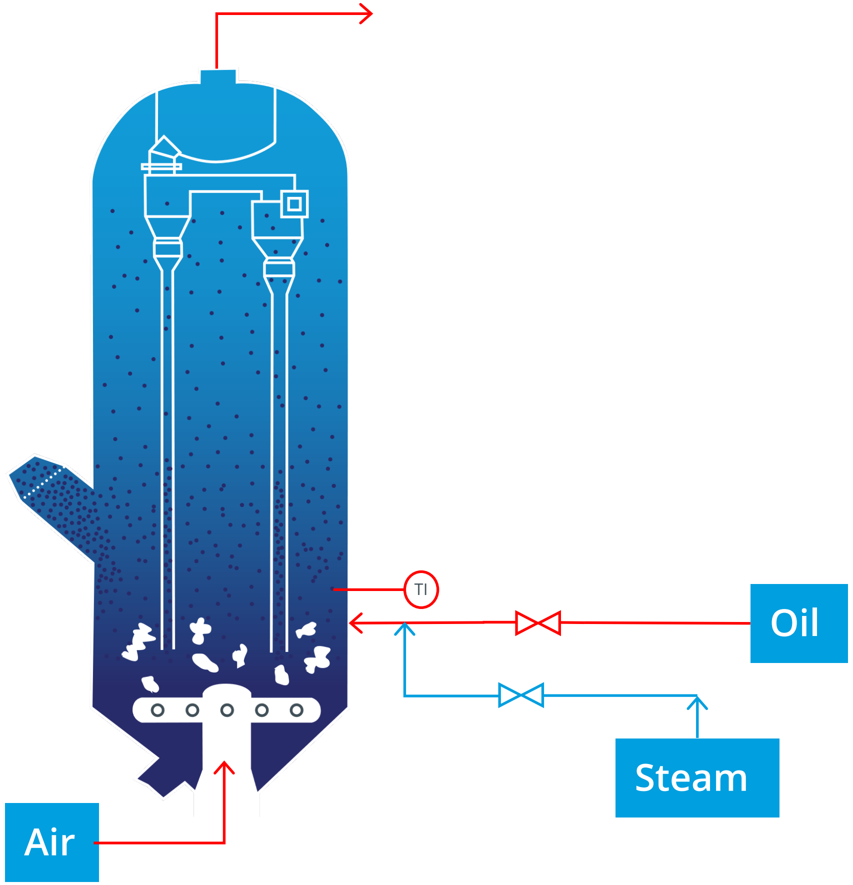
- Regen oxygen deficient prior to feed-out ("behind the burn")
- Significant coke accumulation on catalyst in the regenerator

Unit heat-up commenced for restart

- Airline heater lit & regen heated up to
- When requisite temp for torch oil achieved, introduced torch oil

Torch oil light-off resulted in rapid, uncontrolled temp increase

- Could not correct with torch oil reduction
- Likely reached ignition temperature of coke on catalyst
- Excess O2 high enough to maintain full combustion with coke combustion
- Significantly exceeded design temp of cyclone & grid internals



Keys to Safe Torch Oil Use

2. Temperature, Scenario #2

BACK

Poor Torch Oil Distribution & Temp Excursion

Scenario description:

Large FCC regen with poor torch oil nozzle reliability

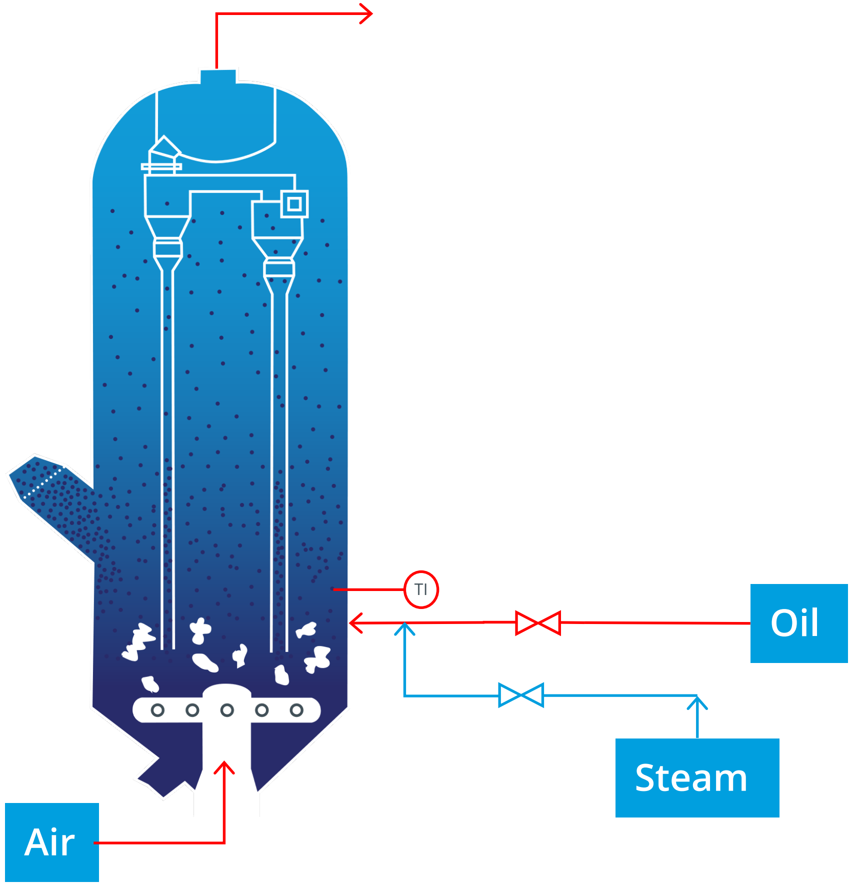
- Most plugged and/or damaged, only a few available in limited portion of regen

During FCC start-ups, torch oil introduced for regen heat-up

- High torch oil rate per nozzle, poorly distributed around circumference

High localized combustion rate

- Resulted in high local bed and dilute phase temps, significantly exceeding design temps locally
- Also resulted in flue gas CO exceedances



Keys to Safe Torch Oil Use

3. Level or Density

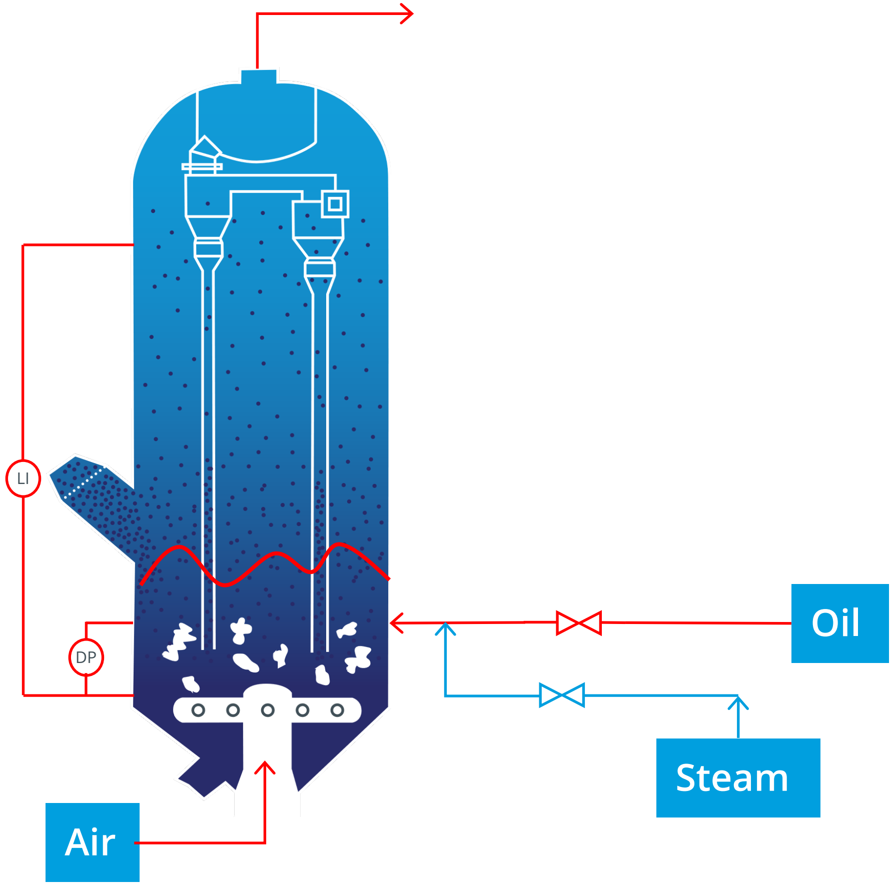
BACK

The torch oil nozzles must be submerged by catalyst so the oil can burn properly and the heat can be absorbed.

- Each unit should have its own guidelines related to the level/density requirements.

The bed elevation should be verified. Calculation should consider the measured level and anticipated (or measured) density.

- In startup scenario the regenerator bed may be more-dense than normal operation, giving a lower bed elevation.
- The actual bed elevation should be confirmed by calculation or instrumented telltale



Keys to Safe Torch Oil Use

4. Composition

BACK

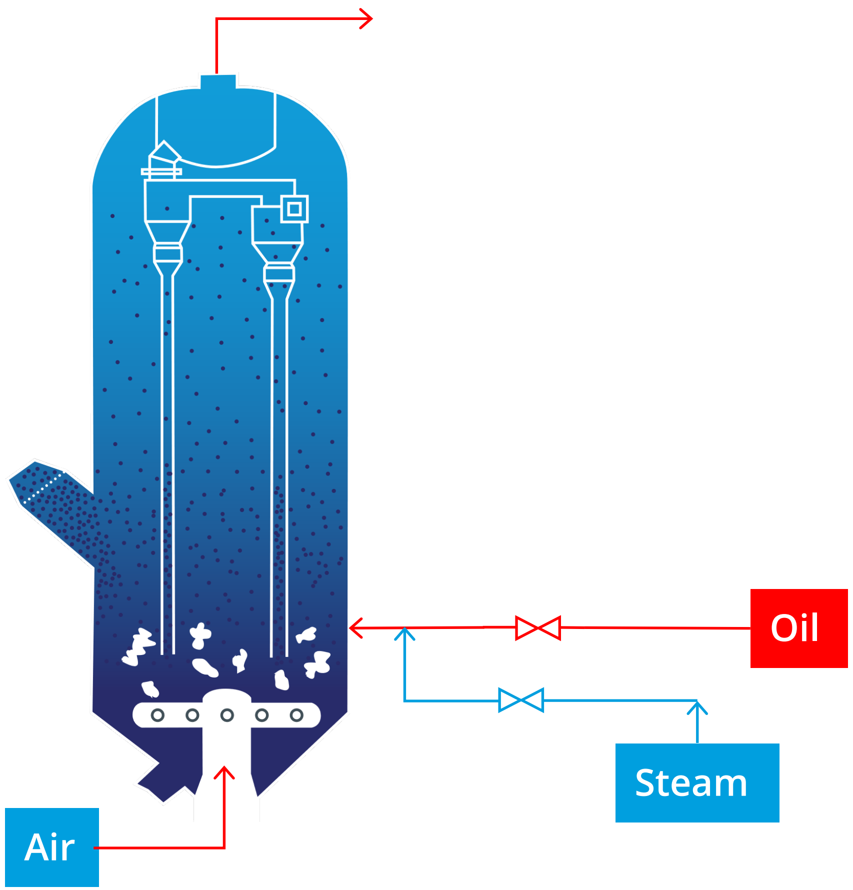
Light oils like LCO may vaporize too quickly in the regen to burn properly.

- Can lead to an explosive mixture in the flue gas system.

Heavy oils such as VGO or main column bottoms are often preferred for torch oil.

If an alternative source will be used, assure that:

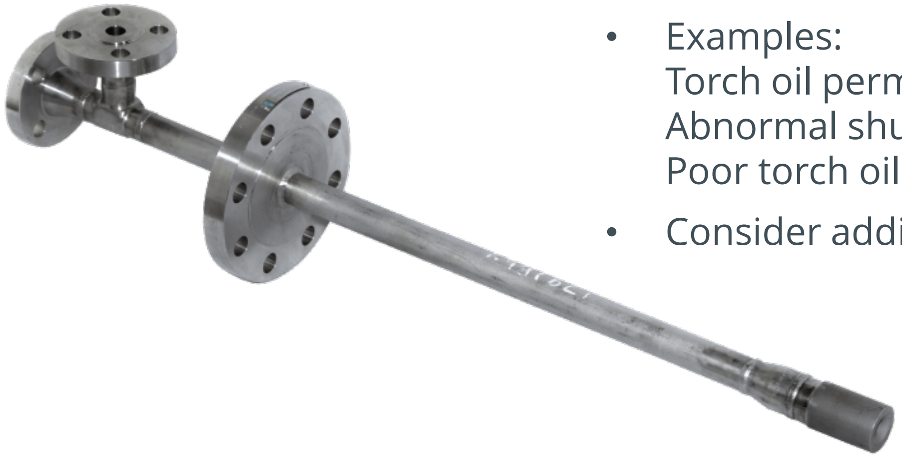
- *5% boiling point is > 390℉*
- *50% boiling point > 600℉*



Keys to Safe Torch Oil Use
Summary

BACK

There are many examples from around the industry in which improper torch oil use has led to incidents or near-misses.



Procedures should conform to safe practices for torch oil introduction and use:

- Air rate sufficient to fully combust all fuel, maintain excess O2.
- Temperature is high enough for torch oil light off
- Catalyst level is high enough to submerge torch oil nozzles and absorb heat
- Torch oil is not too light

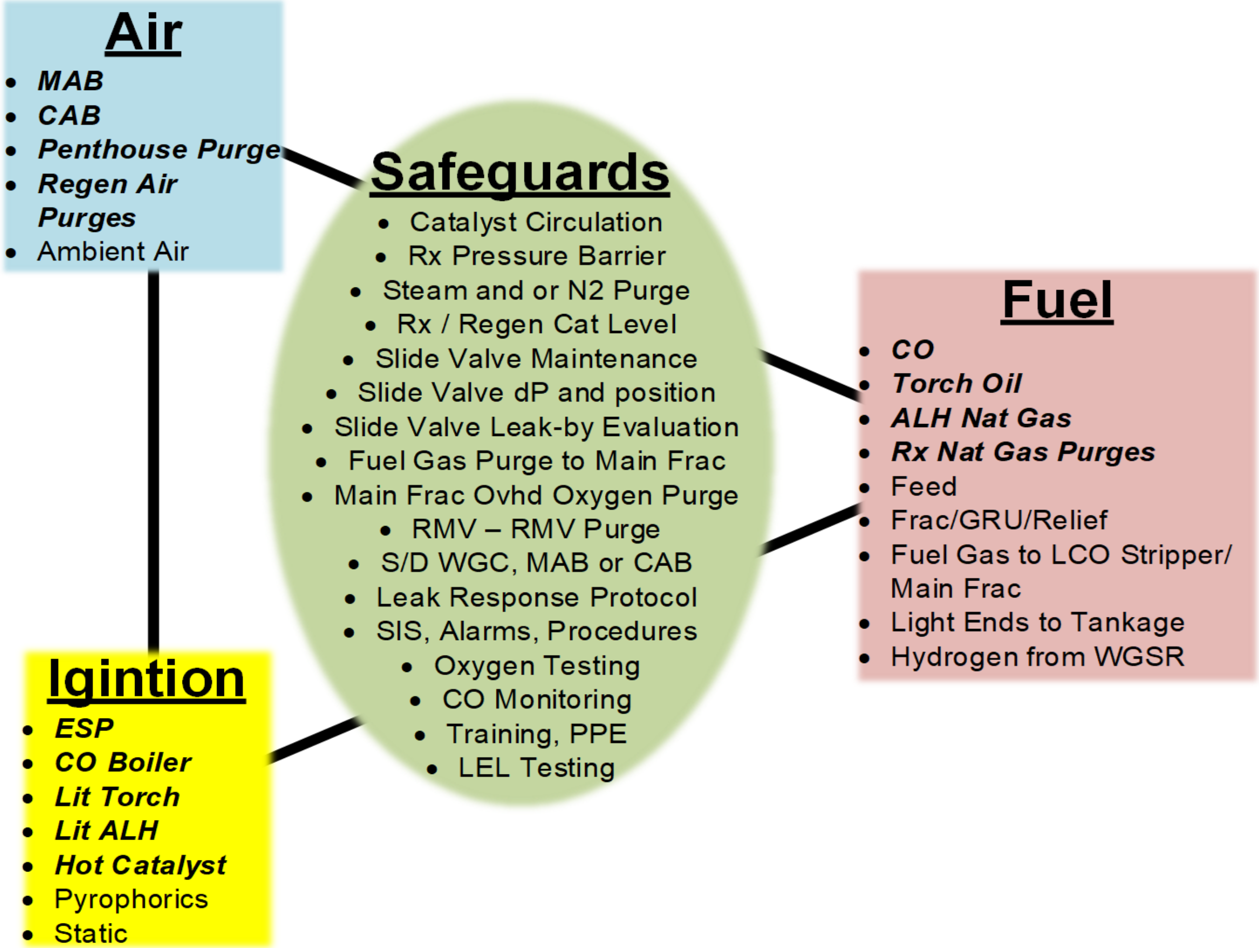
Carefully consider and manage risks if introducing torch oil in abnormal conditions:

- Examples:
  Torch oil permissive / SIS system(s) are compromised or defeated.
  Abnormal shutdown resulted in high coke or oil accumulation on regen catalyst
  Poor torch oil distribution from damaged or inoperable nozzles
- Consider additional safeguards: LEL checks, bypass ignition sources, etc.

Exercise
Bingo

Almost Done. One last exercise!

Exercise **Bingo**



BACK–UP

Slide Valve Online Erosion Monitoring (cont'd)

Common contributing factor in recent high-consequence FCC incidents:

- Slide valve erosion enabling higher than design gas leakage.
- Creating an explosive hydrocarbon/air mixture.

Catalyst slide valves are not gas-tight

- Should never be relied on as single defense for air/HC separation.
- The hydraulic restriction from catalyst held in the standpipe makes valve integrity important for safe standby op's

Practice share for "Online Monitoring of FCC Slide Valve Erosion"

- Continuously monitor for damaged/compromised valves
- Raise awareness about the potential for gas leakage in standby
- Enable planning: procedure mods, turnaround repairs, increased operator training focus for abnormal situations

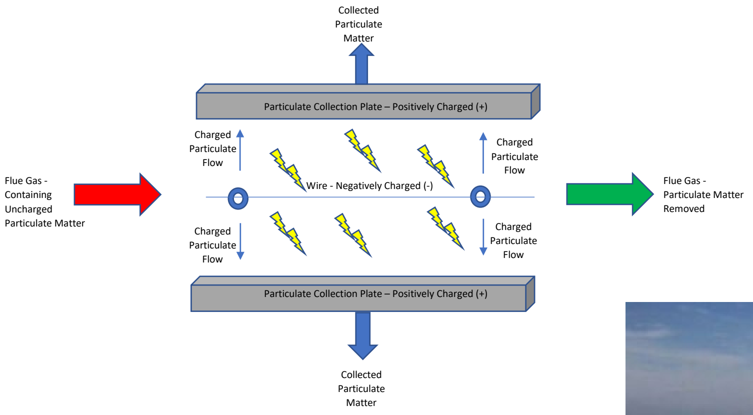
Safe ESP Operation (cont'd)

Electrostatic nature of ESP's presents ignition risk

- Potential for high CO or hydrocarbon >LEL in vapor inlet
- From incomplete combustion of: torch oil, DFAH fuel gas, CO boiler aux gas, hydrocarbon backflow from frac, etc.
- Potential explosive mixture with excess O2 from regen air or ESP penthouse purge

The following controls may reduce explosion risk

- Procedures indicate conditions required to energize / de-energize. Avoid automatic re-energizing, or energizing during high risk periods
- Monitoring of process conditions and flue gas composition, especially during non-routine operations
- Consider re-energization interlocks, including SIS's for the FCC, DFAH & CO boiler; and analyzers for inlet combustibles and/or CO
- ESP shutdown system function testing & change management



ESP Basic Design

Torrance 2015 Incident: ESP Damage
CSB Investigation Report, Figure 18

Keys to Safe Torch Oil Use

1. Excess O_2, Scenario #2

BACK

Hydrocarbon Release from Stack

Scenario description:

Refinery steam outage caused FCC to lose majority of air supply

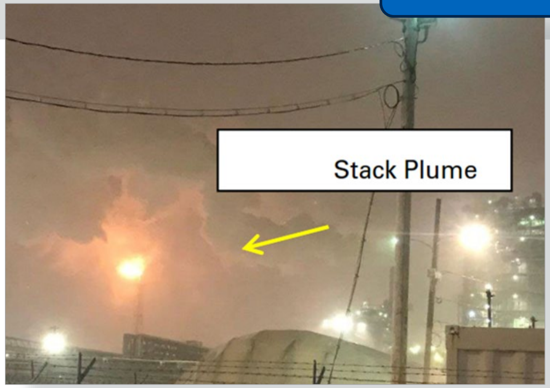
- Feed rate reduced to minimum
- Torch oil added as regenerator temperature decreased

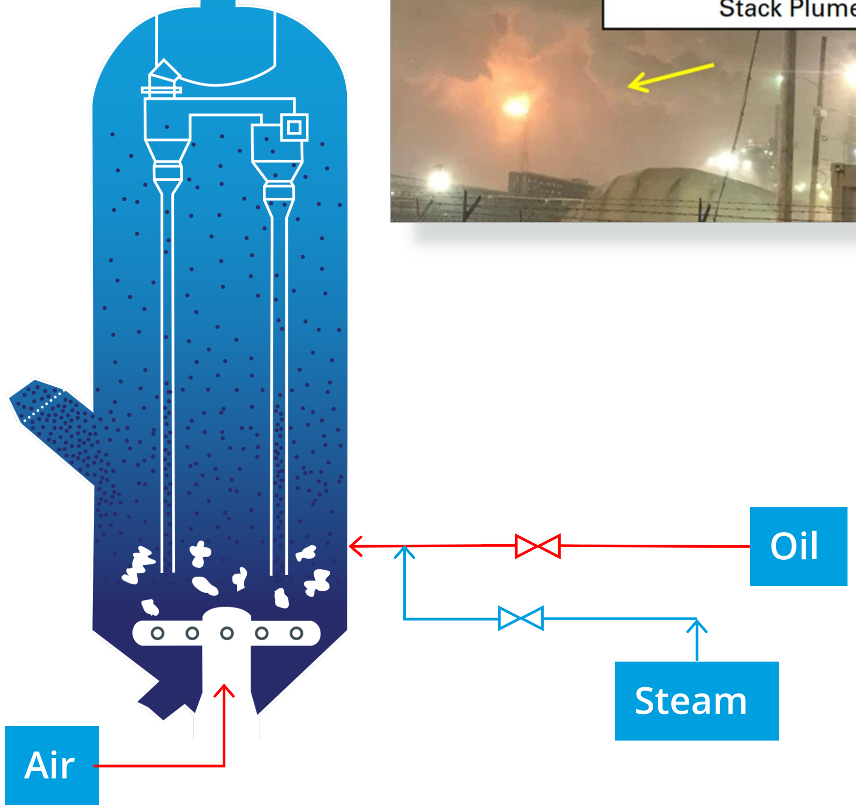
Regenerator temperatures continued to drop:

- O2 fell to 0, CO at max scale
- TO control valve increased, but temperature did not respond

Vaporized, un-combusted oil escaped regen to flue gas to stack

- ESPs were energized but did not deflagrate
- Cloud of oil spread across the refinery, causing 5 first aid cases





Keys to Safe Torch Oil Use

1. Excess O_2, Scenario #4

BACK

Hydrocarbon Release from Stack

Scenario description:

Startup after turnaround with new air distributor design

Torch oil flow increased for regen heat-up, with excess O_2 reading ~4%

- Temperature did not respond
- Some confusion on how the modified system should respond vs. past
- TO regulator eventually reached 100%, but still no temperature response

Yellow plume observed from the regen stack

- Regen catalyst also observed to be very dark

Fortunately able to recover without ignition

- Torch oil slowly reduced; regen temperatures went very high during recovery.
- Later found that O2 analyzer not reading correctly