Non-Routine Operation

Startup, Shutdown, Emergency Procedures

Learning Objectives

Overview of common procedures and safeguards for FCC non-routine operation.

Flavor · Practice Shares

FCC Pre and Post Action Review

FCC Important Procedure Safeguards

Deep Dive · Emergency Scenarios

Exercise · Family Feud

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Flavor
Pre and Post Action Review

Pre Action Procedure Review

Confirm key safeguards are addressed and understood by all.

Ask if the current situation deviates from existing procedure(s)?

Update existing procedure for current situation.

Review updates with stakeholders before implementing.

Post Action Procedure Review

Did all safeguards work as expected?

What went well?

What did we learn?

Revise procedures to capture learnings for the next time.

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Pre and Post Action Review - Pause

Are pre/post action reviews common at your site?

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Flavor
Important Procedure Elements

The purpose of this document is to share practices used to develop and maintain Startup, Shutdown, and Emergency Procedures for the safe operation of a Fluidized Catalytic Cracking (FCC) Unit. A comprehensive set of procedures is required by the OSHA PSM standard (OSHA 1910.119 - Process safety management of highly hazardous chemicals). This practice share will list the generally-accepted list of Emergency Scenarios for a typical FCC Unit which require specific operating procedures.

Shutdown, Startup, and Standby

All of these modes have similar hazards!

Shutdown · immediately after feed is removed on an emergency or normal basis.

Startup · preparing for feed introduction, startup is never an emergency.

Standby · time between shutdown and startup, duration can be undefined and unit status can be defined by one of the three modes (slumped, fluidized, or circulating)

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Important Procedure Elements

Shutdown

Immediate "Safe Unit" Steps or Safeguards:

Isolate all hydrocarbon sources (feed, quench, lift gas, torch oil, natural gas, purges)

ESP is de-energized

COB burners are isolated

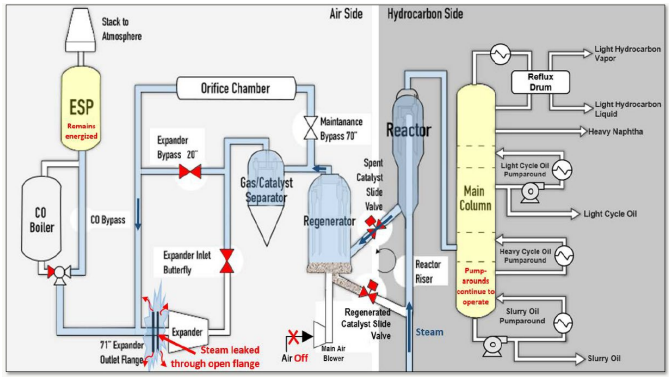
Control Main Column Level

Verify LEL free Regen prior to MAB restart.

Ensure slide valves closed and monitor any leaks

Maintain Reactor inert and highest pressure in the system (Regenerator < Reactor > Fractionator)

Ensure forward flow from Reactor to Fractionator (sour water rejection, flare valve position)



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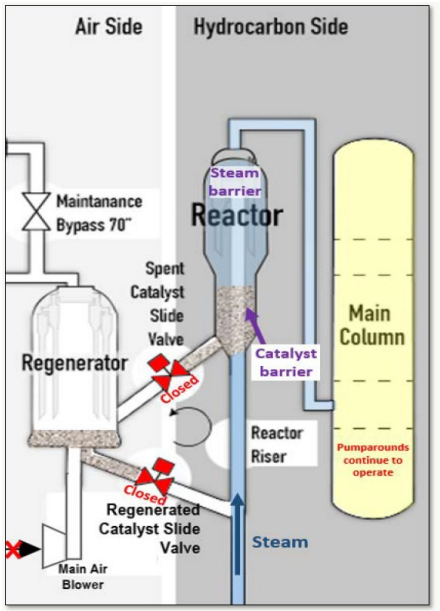
Important Procedure Elements (cont'd)

Transition to Standby



Transition to Standby Safeguards:

Maintain Reactor inert and highest pressure in the system (Regenerator < Reactor > Fractionator).

Ensure forward flow from Reactor to Fractionator (sour water rejection, flare valve position).

Verify Fractionator Overhead O2 is < 2% (purge as needed).

Close Reactor Overhead valve/install blind (duration dependent).

Switch Reactor steams & fuel gas purges to N2 if possible.

Shutdown/Isolate Wet Gas Compressor

Ensure slide valves closed and monitor any leaks

Verify LEL free Regen prior to MAB restart.

Introduce air slowly and monitor for temperature excursions on MAB restart.

Temperature and level indications will not be representative of the bulk inventory with the MAB down.

Follow torch oil safeguard prerequisites before injecting torch oil

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Important Procedure Elements (cont'd)

Shutdown (transition to Standby)

MAB Running Steps:

Maintain Reactor inert and highest pressure in the system (Regenerator < Reactor > Fractionator).

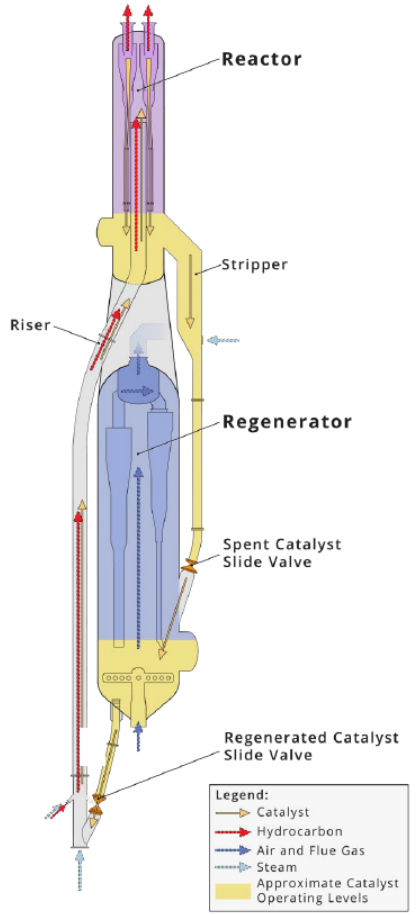
Ensure forward flow from Reactor to Fractionator (sour water rejection, flare valve position).

Verify Fractionator Overhead O2 is < 2% (during dry circulation)

Switch Reactor steams to N2 where feasible.

Close Reactor Overhead valve/install blind (duration dependent).

Shutdown/Isolate Wet Gas Compressor



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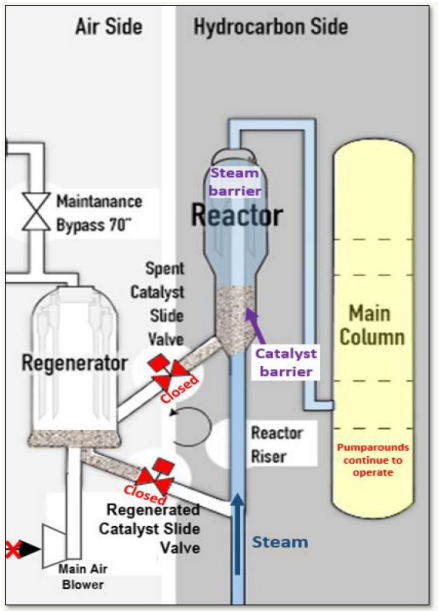
Important Procedure Elements (cont'd)

Shutdown (transition to Standby)



MAB Running Steps (cont'd):

Air Heater Operation –

Ensure adequate DP between fuel gas source and Regen.

Verify fuel gas composition/ liquid free.

Regen Dense Bed temperature must be 800°F minimum for torch oil introduction.

Verify torch oil ignition with temperature rise within 2-3 minutes.

Manage catalyst attrition/deactivation while on torch oil with fresh/flush catalyst additions.

Target Regen Dense Bed Temperature ~1350°F to minimize CO emissions.

Monitor Regen catalyst losses frequently (opacity, WGS solids).

Ensure Primary Cyclone Inlet velocities are above 20 ft/s.

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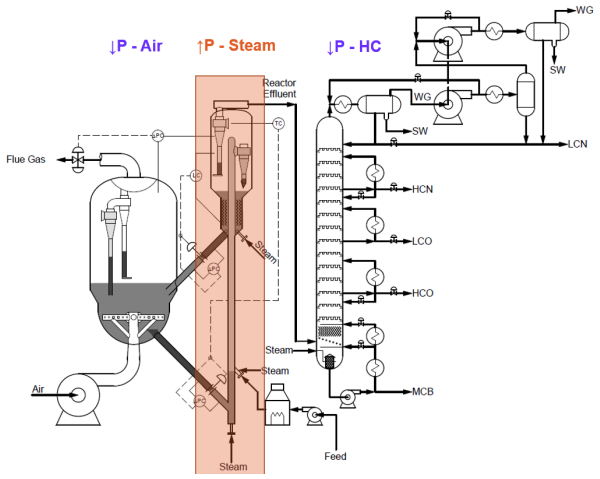
Important Procedure Elements (cont'd)

Start Up



Catalyst Circulation Steps:

Ensure isolation of all hydrocarbon sources to the Reactor (feed, quench, lift gas, purges).

ESP de-energized until ~60% feed rate and stable.

Maintain Reactor inert and highest pressure in the system (Regenerator <Reactor >Fractionator) until adequate slide valve DPs and catalyst circulation are established.

Ensure forward flow from Reactor to Fractionator (sour water rejection, flare valve position).

Maintain Fractionator Overhead O2 is < 2%.

Drain Reactor Wye/J-bend low points and **ensure water free prior to initiating catalyst circulation**.

Drain water from main column before heating up.

Raise Regen pressure above Reactor pressure only after catalyst circulation and levels have stabilized (where applicable).

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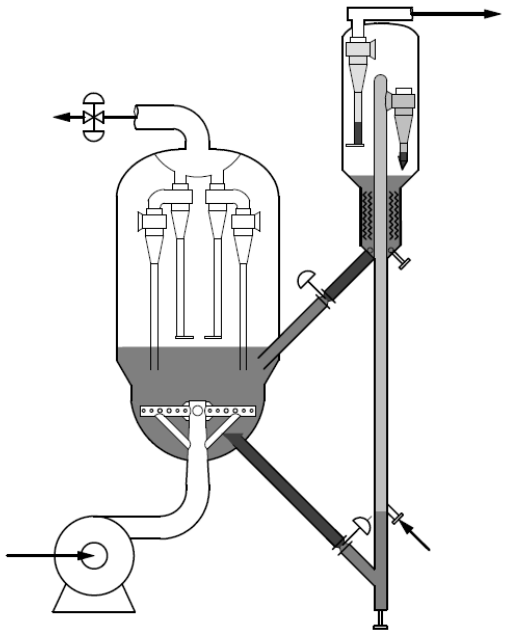
Important Procedure Elements (cont'd)

Start Up



Catalyst Circulation Steps (cont'd):

Manage catalyst attrition/deactivation while on torch oil with fresh/flush catalyst additions.

Target Regen Dense Bed Temperature ~1350°F to minimize CO emissions.

Monitor Regen catalyst losses frequently (opacity, WGS solids).

Ensure Primary Cyclone Inlet velocities are above 20 ft/s.

Open Regen Catalyst Slide Valve and inventory Reactor.

Open Spent Catalyst Slide Valve and establish batch/continuous catalyst circulation.

Raise Regen pressure above Reactor pressure only after catalyst circulation and levels have stabilized (where applicable).

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Deep Dive
Emergency Procedures – Key Actions

Why?

Non-routine operation, such as startup, shutdown, standby or emergency operations are when the FCC unit is most vulnerable.

Often, operations personnel are relied on to make decisions, with or without well defined protocols in place.

How?

Process safety near misses and events are avoidable!

Develop and maintain procedures used in non-routine operating scenarios for the safe operation of the FCC Unit.

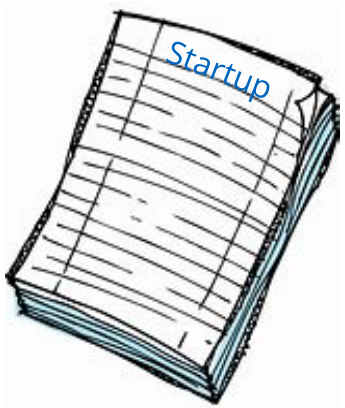
What?

List of generally accepted Emergency Scenarios for a typical FCC Unit which require specific operating procedures.

Response necessary to reach a safe state, post event restart, and general hazards for each emergency scenario.

General operating steps for normal startup, normal shutdown will also be covered with corresponding hazards.

Checklist for use in auditing startup/shutdown procedures to ensure a safe and reliable operation.



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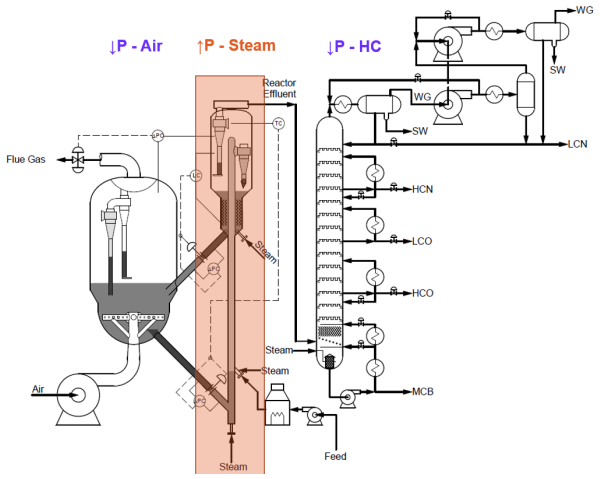
Important Procedure Elements (cont'd)



Pause for discussion …

What are common safeguards during FCC Shutdown/Startup?

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Emergency Procedures Common Scenarios

Summary

Common FCC Emergency Scenarios

- Loss of Combustion Air
- Loss of Steam
- Loss of Flue Gas Cooling/BFW
- Flue Gas Slide Valve Failure
- Loss of Slurry Pumparound
- Power Failure
- Loss of Cooling Water
- Loss of Instrument Purge
- Spent Slide Valve Failure
- WGC Failure
- Regen Slide Valve Failure
- Loss of Instrument Air
- Oil Soaked Catalyst

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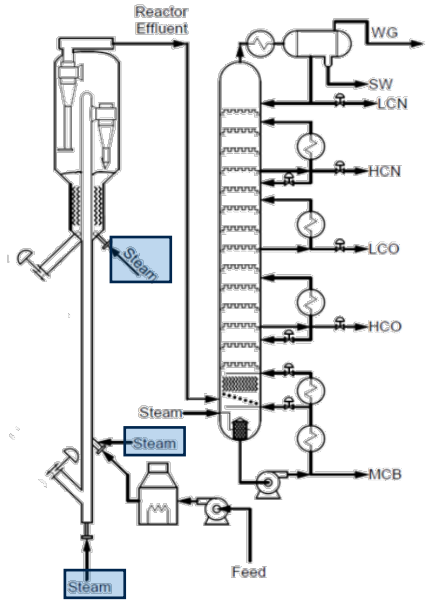
Emergency Procedures
Key Actions - Loss of fill in the blank

There are about 20+ common scenarios that will result in an FCC shutting down.



But ~ 10 key safeguards that can avoid mixing of air and hydrocarbon with ignition sources.

Key Actions

Focus on safeguard verification during these periods of Shutdown/Standby/Startup

Operation.

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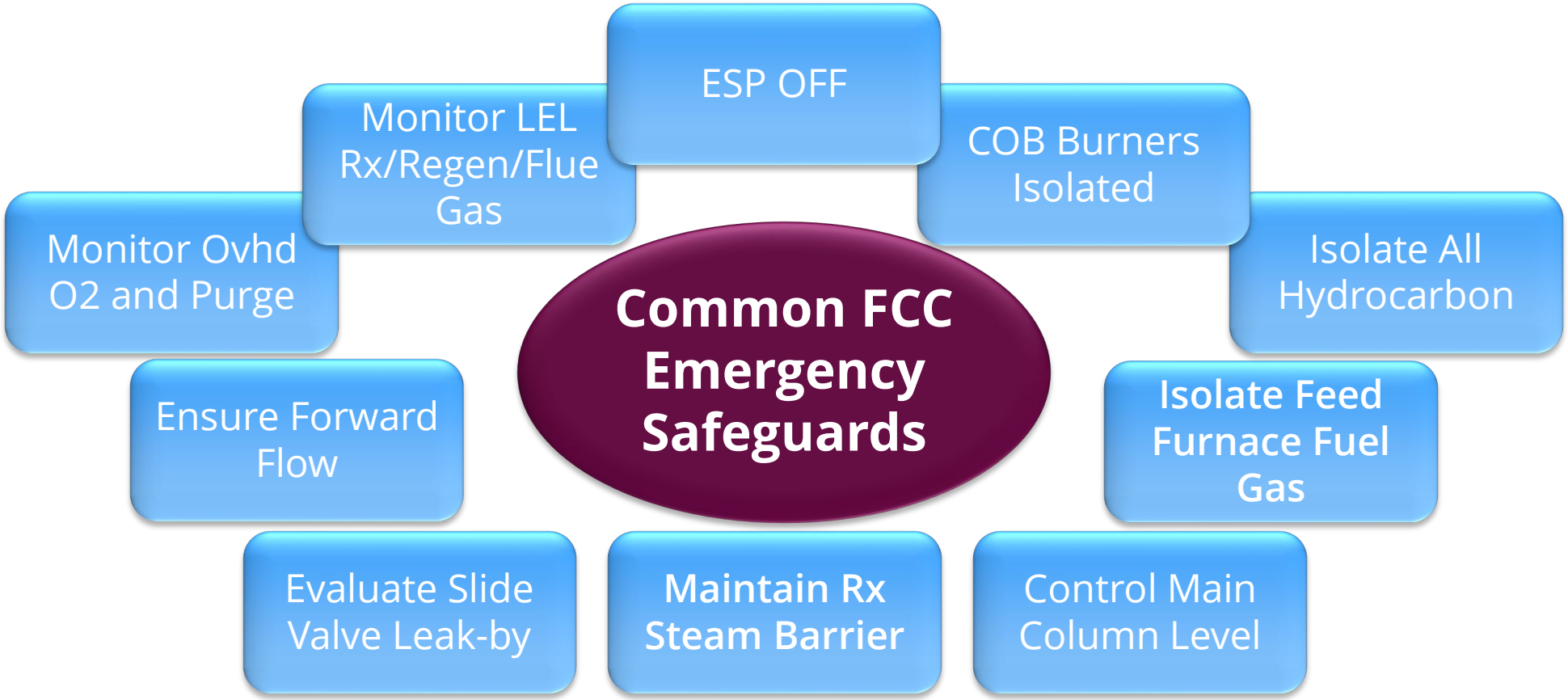
Emergency Procedures Key Safeguards

Summary



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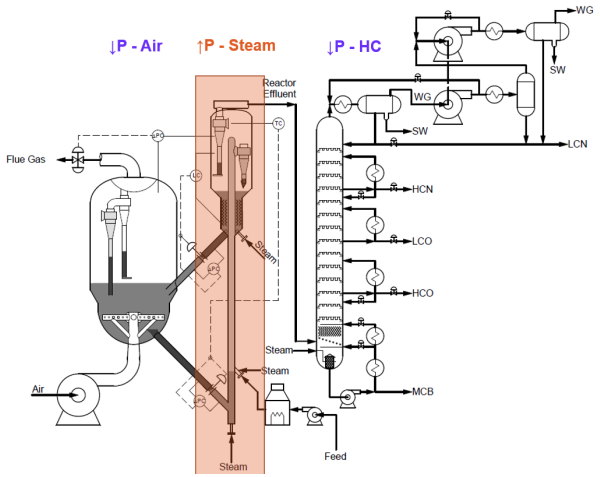
Important Procedure Elements (cont'd)



Pause for discussion …

Are there any safeguards missing?

Any safeguards that are unfamiliar?

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Emergency Procedures **Summary**

BACK

There are many examples from around the industry in which common safeguards would have mitigated a variety of scenarios.

Review your procedures and training to confirm these safeguards are clear and understood by all personnel.

Actions to take after this deep dive:

A good set of procedures has Industry Know How built in.

Review the safeguards covered in your specific unit scenario procedures.

Ask are the procedures steps clear to ensure the safeguard will be implemented as intended.

Modify as needed to mitigate risk!

Conduct pre/post action reviews to incorporate lessons learned ASAP

Don't wait to familiarize yourself with the procedures and key safeguards

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Appendix…

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Emergency Procedures Key Actions - Loss of Main Air

Is this an automatic ESD input? What standby mode?

What is regenerator environment like?

Do you inject steam?

Issues with MAB check valve?

Ideas to help when restarting air flow?

Other Key Actions?

Key Actions

Isolate all hydrocarbon sources into reactor/regen (including torch oil and downstream COB burners)

Loss of air impacts unit pressure balance; adjust accordingly.

Regenerator may still contain combustibles:

If temps remain >800 ℉ these will be consumed when air is reintroduced.

If temps drop <800 ℉ these may be below auto-ignition and create explosive mixture when air is reintroduced.

Steam injection can result in CO/H2 by reacting with coke and water.

Test dilute phase/flue gas line for LEL; Nitrogen purge if needed.

Ignition sources in flue gas system should be de-energized.

Use plant air downstream of MAB check valve to ensure open path before starting small flow of air to regenerator.

One of most significant emergencies in FCC and the unit must be shut down.

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Emergency Procedures Key Actions - Loss of Flue Gas Cooling/ Boiler Feed Water

What happens? What equipment is at risk?

What is response?

What standby mode? Can unit stay online?

Key actions?

Loss of cooling can damage flue gas cooler tubes, expose downstream equipment to higher than design temperatures.

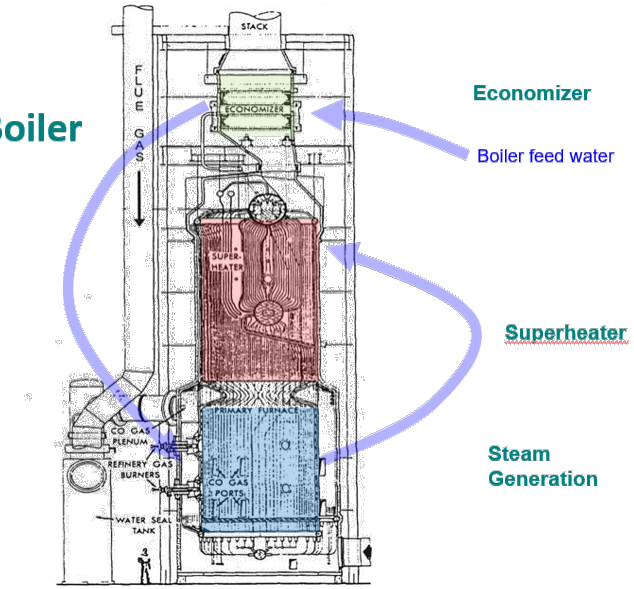
Key Actions

Some units may choose to shut down MAB.

Alternatively, some may choose to remove sources of heat (FCC coke, torch oil, DFAH, etc.) and leave MAB online.

Be aware of impact on unit/ refinery steam balance.

Re-introducing water into hot equipment can create sudden pressure increases if water level has been lost.



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Emergency Procedures
Key Actions - Loss of Cooling Water

Where do you see first/most/ worst impact?

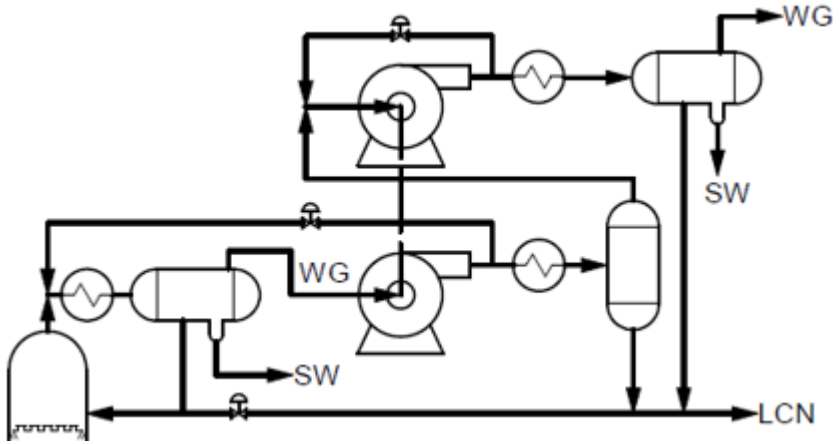
How long can you survive?

What is highest risk equipment?

What standby mode?

Key Actions?

Loss of cooling water can result in equipment temperature and pressure exceedances.



Key Actions

Generally, if cooling water not restored in ~10 mins the unit must be shut down.

Highest risk equipment

WGC (high temps and potential damage to compressor).

Turbine drivers for most key equipment · MAB, WGC, MCB.

Assess potential equipment damage before restarting.

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Emergency Procedures Key Actions - Power Failure

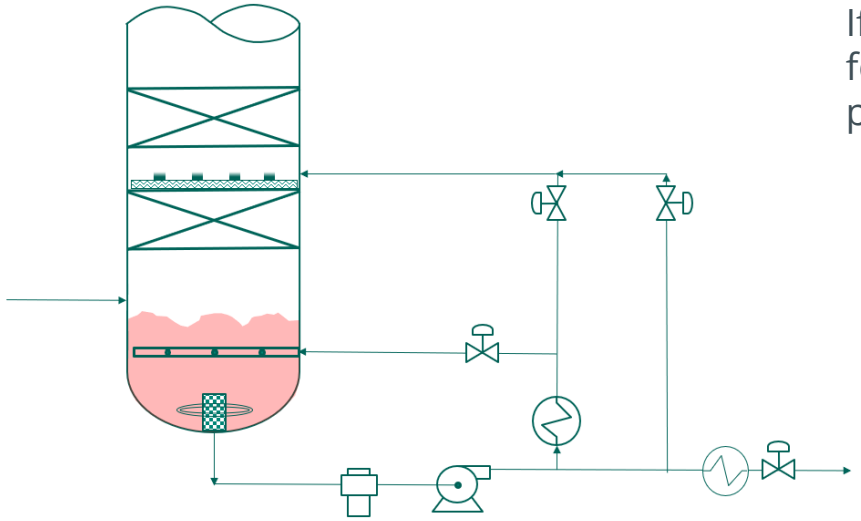
What equipment stays on?

What standby mode?

Key Actions?

Other procedures to follow?

Only left with steam-driven equipment and DCS (if equipped with UPS).



Key Actions

Unit must be shut down.

Lighten Main Column bottoms with LCO and pump down level.

If MCB flow, is lost follow this emergency procedure.

If MAB must be shut down, follow loss of air emergency procedure.

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Emergency Procedures Key Actions - Loss of Steam

Full or partial loss? Pressure?

What valves should be prioritized?

Is FCC steam importer or exporter?

Key Actions?

What standby mode? Concerns upon return of steam?

Assess Full or Partial Steam Loss

Distributors usually designed to operate 60% of normal and not plug.

Prioritize steam flows to areas where catalyst is still present.

FCC can be self-sufficient depending on unit design.

Key Actions

For total steam loss, unit must be shutdown if not self-sufficient.

Priorities include clearing riser and inerting reactor.

Close reactor isolation valve if available or install reactor overhead blind (duration dependent).

Utilize nitrogen if available downstream of control/check valves.

Be aware of potential for condensate upon re-energizing steam system.

Source: CSB

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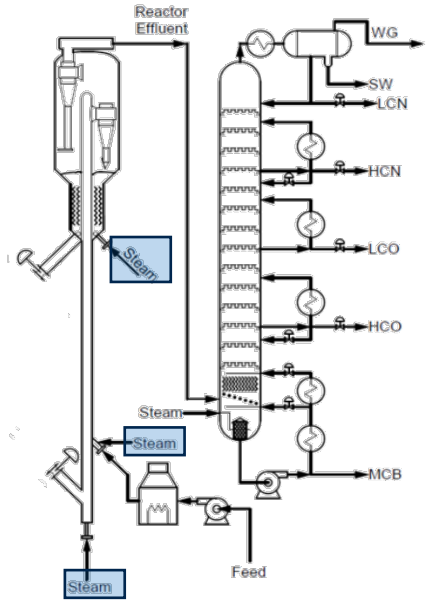
Emergency Procedures
Key Actions - Loss of Instrument Air

What happens?

All valves impacted the same way or at same time?

Key equipment impact:

- MAB vent
- Riser lift steam
- Feed nozzle steam
- Slurry pumparound



Loss of instrument air results in control valves going to their fail position.

Often, different valves will have different air requirements so all may not fail at same (decreasing) instrument air pressure.

Key Actions

MAB vent valve opens and SIS will trip unit on low air flow.

Feed flow closes.

Riser lift steam and feed nozzle steam valves open (block in/operate on bypass).

Slurry pumparound flow (at least one path) fails open to keep MCB cooling.

If air is not restored, the unit must be shut down.

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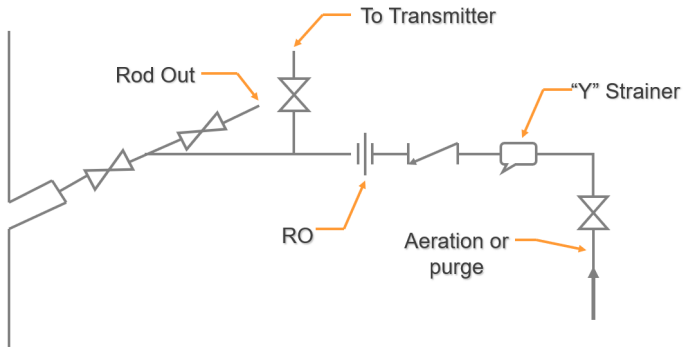
Emergency Procedures
Key Actions - Loss of Instrument Purge

Do you trust instrument readings?

Do you have a backup? Automated? Incorporated into ESD system?

Key Actions?



Loss of instrument purge results in inaccurate instrument readings of primary concern on the Reactor and Regenerator.

Newer units can have an ESD activation on loss of purge.

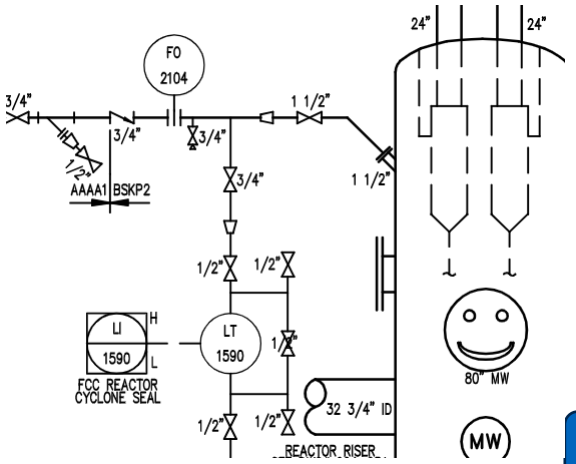
Often Reactor purges will have a backup, pressure should be monitored downstream of the backup source.

Catalyst levels are inaccurate – resulting in catalyst carry over/loss of slide valve DP.

Slide valves DPs are inaccurate – reversal of Regen to/from Reactor unit does not trip.

Key Actions

If instrument readings are not accurate, the unit could not trip when it should and should be safely shutdown instead on loss of instrument purge pressure.



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Emergency Procedures
Key Actions - Spent Slide Valve Failure

What happens?

What is more hazardous – open or closed?

What is standby mode?

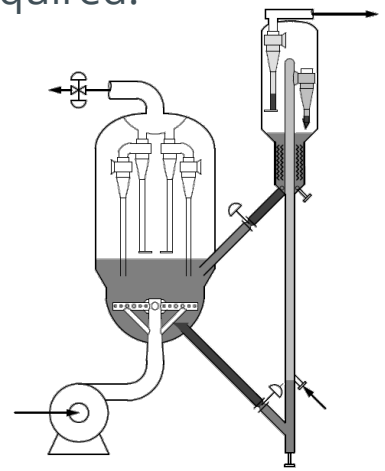
What can you do before shutting down?

Ultimately, MAB will need to be shut down and unit depressured if failed open.

Most hazardous is spent slide valve stuck open.

Easy path for air to enter reactor.

'Negative reactor/regenerator dP required.



Key Actions

Circulating catalyst prevents loss of catalyst level and open path for air to enter reactor.

MCB will need lightened/ pumped out/inerted, catalyst withdrawn, etc.

WGC/MAB shut down, unit depressured, install RX OH blind.

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Emergency Procedures
Key Actions - Regen Slide Valve Failure

What happens?

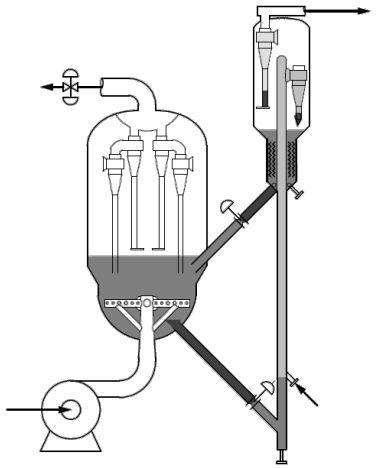
Any other variables you can use?

What standby mode?

What can you do before shutting down?

Lose ability to control reactor outlet temperature (on most units).

Other options to help – lift/riser steam, reactor pressure.



Key Actions

Withdraw as much catalyst as possible before shutting down unit.

Shut down MAB when unit is tripped/feed bypassed.

Stop steam to riser to plug wye and prevent reversal.

Ultimately, MAB will need to be shut down and unit depressured if failed open.

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Emergency Procedures
Key Actions - Flue Gas Slide Valve Failure

Stay online? If not, which standby mode?

What happens if it goes closed?

What happens if it goes open?

Key actions?

Likely survivable if only 1oo2 is lost.

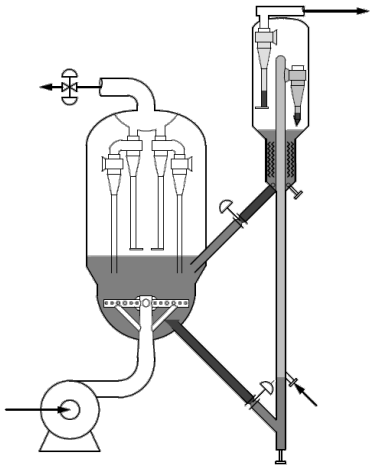
Fail toward closed – MAB surge control opens vent valve.

Air reduction to regenerator.

Potential loss of spent slide valve dP.

Fail toward open – high velocities and potential catalyst carryover.

Potential loss of regen slide valve dP.



Key Actions

Must be able to adequately control pressure balance.

Potential to control locally in the field.

Unit must be shutdown if pressure balance cannot be maintained.

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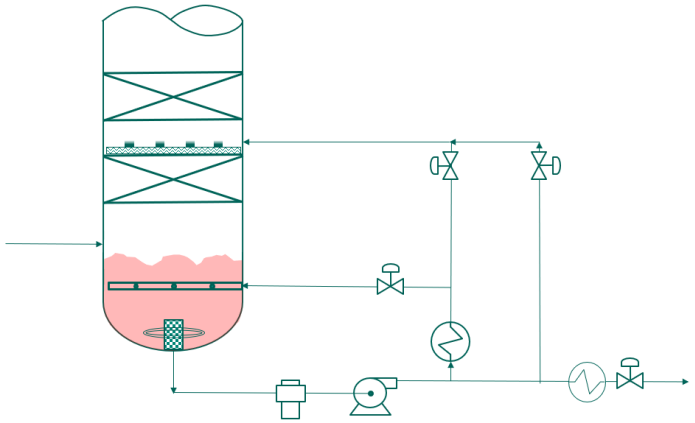
Emergency Procedures Key Actions - Loss of Slurry Pumparound Flow

Stay online? If not, which standby mode?

How long can you live with no flow? Why?

What are Key Actions?



Main column bottoms circuit usually removes 30+% of heat from reactor vapor.

If flow is lost for >10 mins the unit should usually be shutdown due to:

Bottoms pool residence time, temperature increase, and coke formation increases.

High temperatures can damage main column internals.

Potential entrainment of catalyst fines up the main column.

High liquid level/potential reactor backpressure and tray/internals damage.

Key Actions

Start spare slurry pump.

Stop catalyst circulation if not re-established.

Remove material from column (reduce bottoms level).

Keep temperatures down (reduce LCO draw).

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Emergency Procedures Key Actions - WGC Failure

Stay online? If not, which standby mode?

Most common cause?

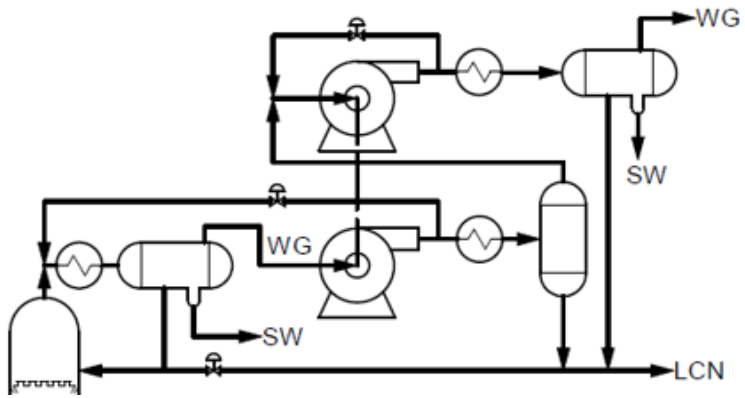
Does unit size come into play?

Key Actions?

Cause – Mechanical, aux equipment or instrumentation.

Applicable flaring regulations will dictate if the unit should stay online.

Reduce feed rate and/or reactor temperature to reduce impact.



Key Actions

Main Column/Reactor pressure will need controlled via vent to flare.

Valve configuration/process control tuning considerations.

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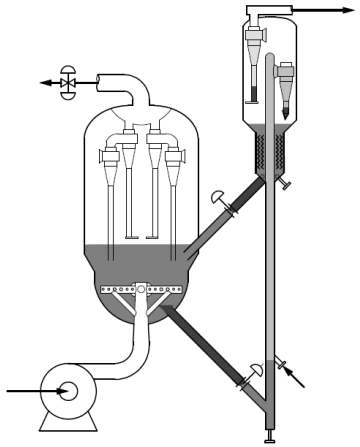
Emergency Procedures
Key Actions - Oil-soaked Catalyst

When is unit most at risk? What modes of operation?

Is this only reactor-side issue?

How can you tell?

Key Actions to take?



Cause – Feed not diverted from Riser or Torch Oil injected below ignition temp.

Check bottom of Riser for liquid and drain.

Check catalyst sample for color/oily residue.

Check Regen LEL if MAB is shutdown.

Key Actions

Shutdown unit, leave MAB online if possible (establish Standby 2).

Slowly transfer catalyst to Regen.

Monitor Regen temperatures and stop when initial increase is seen.

Track amount/time open for spent slide valve and temperature increase.

Increase as feasible without exceeding Regen internals design temperature.

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