Fired Heater Hazards of Operating With Fuel-Rich Firebox:
Experience Shared and Lessons Learned

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CCPS
MIDDLE EAST
PROCESS SAFETY
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Introduction

- Bapco operates a 265 MBPD crude capacity refinery, started up in 1936
- At Bapco we have 45 fired heaters:
  - Various configurations
  - Different burner technologies
  - Ages ranging from 5 to 80 years
- Extensive operating experience with fired heaters and their optimisation and troubleshooting
- Full time Subject Matter Expert (SME) for fired heaters:
  - Assists operations departments in managing and improving energy and safety performance of fired heaters

Introduction (cont'd)

- As part of the continuous improvement of our operations, Bapco implemented the Bogging Protocol:
  - Instructions to operators on how to detect fuel-rich conditions in fired equipment and take corrective action to prevent explosion

What is Bogging?

- Bogging is the operation of a fired heater with a fuel-rich atmosphere in the firebox
- This operating condition is known by many names e.g. “stalling”, “smothering”
- It can be extremely dangerous
- It can quickly escalate into an explosion

What is Bogging? (cont'd)

stack flue gas colour
during bogging conditions

heater explosion following bogging

Signs of Bogging

- Low O_2 and high CO/combustibles (incomplete combustion)
- Draft pulsation or “huffing” of the fired equipment
- Strong vibration
- Black smoke coming out of the stack
- Reduction in process fluid outlet temperature with constant or increasing fuel gas flow
- Strong fuel gas smell in the vicinity of the heater

Causes of Bogging

Bogging is caused by insufficient combustion air or excess fuel gas, which results in incomplete combustion and accumulation of unburned hydrocarbons

- Inadequate opening of burner air registers and/or stack damper
- Induced and/or forced draft fan failure
- Air flow meter malfunction
- Fuel gas control valve malfunction
- Insufficient combustion air supply during rapid increases in heat demand e.g. during start-up, feed cut-in, addition of cold process fluid

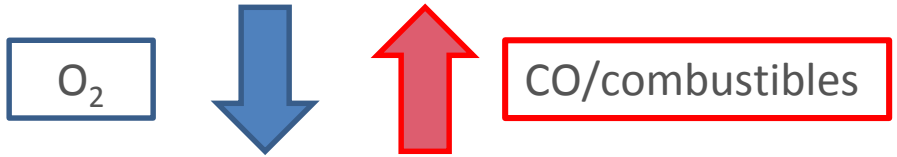
Bapco Bogging Protocol

- Developed to prevent the escalation of bogging incidents
- It establishes a short series of steps to arrest the bogging and safely return the heater to normal operation
- The implementation includes training for the operators to prevent, identify and correct a bogging scenario

Bapco Bogging Protocol (cont'd)

For the purpose of our protocol fired equipment is considered bogged if:

- Excess oxygen (O_2) is below the low O_2 alarm or below 1.0 vol%, whichever is higher, and
- Carbon monoxide (CO)/combustibles are above upper limit of the analyser range or at 1500 vppm, whichever is lower.



Bapco Bogging Protocol (cont'd)

Special considerations:

- Fired equipment not provided with CO/combustibles analysers will rely on excess O_2 readings only
- The fired equipment must be assumed to be in a bogged condition if:
  - O_2 analyser fails and the CO/combustibles level is higher than the high alarm value
  - CO/combustibles analyser fails and the O_2 level is lower than the low O_2 alarm value

Bapco Bogging Protocol (cont'd)

Special considerations:

- Fired equipment not provided with analysers will be considered bogged whenever:
  - The coil outlet temperature (COT) decreases and the fuel gas flow rate increases

Bapco Bogging Protocol (cont'd)

Bogging alerts configured in the DCS with appropriate alarms for each fired heater based on the excess O_2 and CO values defined on this protocol.

When the bogging alert is activated the Control Operator must:

- Place and hold the fuel gas control valve in manual mode
- Notify field crew of the situation and instruct them to evacuate all personnel within the vicinity of the heater
- Slowly reduce fuel gas flow until the all clear is given

Bapco Bogging Protocol (cont'd)

After the bogging alert is cleared:

- Additional air can be added by opening the stack damper or air registers
- The fuel gas flow can then be increased, if required, to return the heater to normal conditions

Bapco Bogging Protocol (cont'd)

WARNINGS

- **NEVER** add air to a bogged fired heater because this could lead to an explosion
- If there is any indication that flameout has occurred, immediately evacuate the area and activate the emergency shutdown system

Case Study: 3CDU Fired Heater

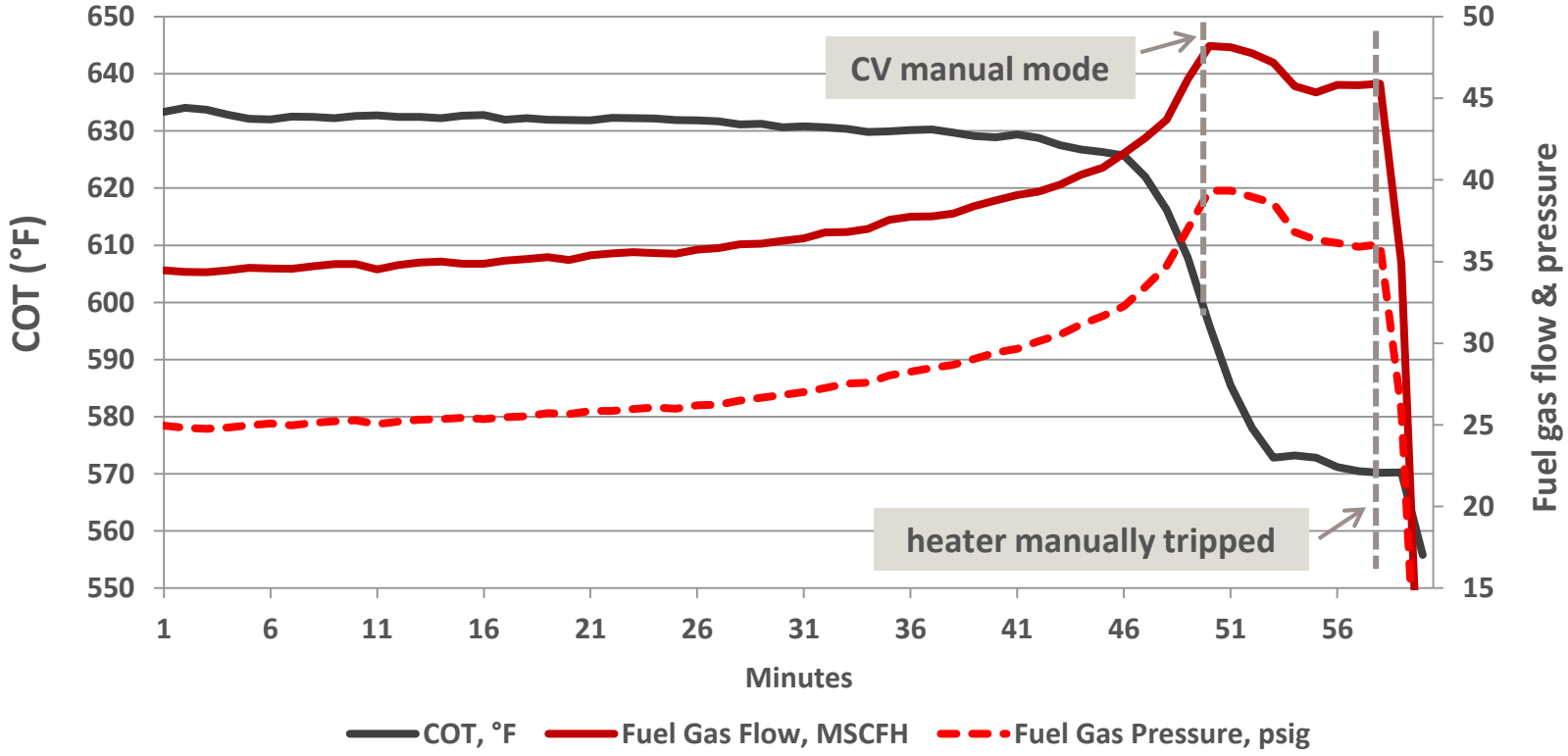
- Fired heater located in No. 3 Crude Distillation Unit (3CDU)
- Designed to process 10 MBPD of crude
- Vertical cylindrical, natural draft, four burners firing upwards
- Not equipped with flue gas analysers
- Manually operated stack damper
- Burner air registers do not have a locking device to maintain the desired opening

Case Study: 3CDU Fired Heater (cont'd)

Description of the incident:

- Reduction in heater outlet temperature and increase in fuel gas pressure and flow was observed
- Fuel gas control valve was switched to manual mode to reduce flow
- Strong vibration and black smoke from stack was observed
- Implemented actions were not enough to control heater firing
- The heater had to be shut down

Case Study: 3CDU Fired Heater (cont'd)



Case Study: 3CDU Fired Heater (cont'd)

Observations:

- Coil outlet temperature (COT) dropped by 60 degF in 15 minutes
- Fuel gas pressure increased by 10 psi in 10 minutes
- Stack damper was seized at 50% opening
- Burner air registers were found almost closed
- Air registers were not provided with a locking device

Case Study: 3CDU Fired Heater (cont'd)

Lessons learned:

- Bogging can develop quickly and pose a risk to personnel and assets
- Trends leading to bogging can be used for early detection
- Stack dampers must be operable at all times
- Burner air registers must have a lock-in-position device
- Operators must be trained on the prevention, detection and correction of bogging

Concluding Remarks

- Bogging is an operating condition that poses a risk to personal and process safety
- Bapco is implementing a refinery-wide protocol to detect and correct bogging in fired heaters, boilers and incinerators
- The detection of bogging can be based on flue gas excess oxygen and combustibles readings or on coil outlet temperature and fuel gas flow
- Inadequate corrective actions can lead to an explosion, hence, operator training is a key success factor

Thank You.

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