Fired Heater Flooding

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Outline

• Definition
• Causes
• Indication
• Response
• Examples
• Prevention
14.2 Flooding

Flooding (substoichiometric operation) is a term used to indicate operation with insufficient combustion air, resulting in unburned fuel or combustibles in the firebox and/or flue gas. As the furnace is typically on automatic coil outlet temperature control, the lack of combustion within the firebox allows the outlet temperature to reduce and the control system calls for more fuel exacerbating the situation. The cycle, if unabated can eventually lead to burner flameout. Before this point the unburned hydrocarbons can result in afterburning.
Heater Flooding Incident

Outside operators:
• Sent to check flames
• Saw low CO reading
• Smelled gas
• Saw heater huffing & puffing
• Saw deflagration blow open heater wall

Issues:
• CO analyzer not in service due to maintenance (not in turnover report to next shift)
• Low O2 alarm incorrectly set too low
• Heater ran out of air
• Reduced heater temps = call for more fuel which flooded heater
14.2 Flooding (cont’d)

Flooding on a natural draft heaters is generally accompanied by erratic firebox pressures or “panting” at the furnace air inlets. With too much fuel and too little air, combustion ceases, pressure is reduced in the firebox allowing more air to enter, as combustion develops, pressure increases in the firebox excluding the air once more. It is the small differential pressures across the natural draft burners that make this situation prevail. It is less prevalent with forced draft systems where cross limiting air fuel ratio control can prevent this situation. Pressure drop across the burners and combustion air system dampens the effect of the increases/decreases in combustion inducted pressure changes.
Unstable Heater

![Diagram of an unstable heater with %O2 and Draft gauges showing values from -0.3 to 0 and 0 to +0.3.](image)
When heater becomes flooded, firebox may shudder, huff, or woof repeatedly. This eventually can cause damage to refractory & heater tubes.

Refractory Damage
Simple Definition of Fired Heater Flooding

Too much fuel in the heater
Fired Heater Flooding

• **Flooding** is a condition in which several or all of the burners alternately flameout & reignite

• **Bogging** is fuel rich operation of the heater to a point where all burner flames are out
Good Operation

-3.1° H2O
Arch draft

500 °F
Stack temp.

3% XS O2
Excess O2

0.0
CO

815 °F
Tube temp.

815 °F
Bridgewall temp

18 psig
Fuel pressure

1550 °F

Burners & heater working as designed

Oil in
Oil out

Stack temp.
Bridgewall temp.

Good Operation
Flooded Heater & After Burning

- High stack temperature
- High tube metal temperature
- High fuel pressure
- Low O₂

Oil in

0%

XS O₂

5000 CO

- Flooded Heater & After Burning

850 °F

1850 °F

4.5° H₂O

1115 °F

28 psig
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API 535 (cont’d)

14.2 Flooding (cont’d)

Other possible causes of flooding may include:

• Fuel compositions beyond the recommended limits of the burner
• Low draft leading to insufficient air entering the burners
• API 556 discusses methods of addressing unburned combustibles within the fuel fired heater protective system.
Possible Causes #1

**Mechanical Issues**
- Stack damper – positive draft in firebox
- Burner registers set too low for firing rate
- Fans – failure or set too low for firing rate
- Instrumentation failure/not calibrated (e.g., O2, CO, draft, fuel flow)
- Fuel control valve fails to respond
- Plugged/fouled gas tips
- Burner flame outs
- Tube failure
Possible Causes #2

Fuel Changes

• Sudden loss of H2 in fuel
• Switching to natural gas
• Sudden addition of heavies (e.g., C3s, C4s)
• Liquid fuel carryover
Possible Causes #3

Operational Failures

- Dampers not adjusted to allow change in operation
- Burners ramped up too fast
- Heater operated to draft limit
- Sudden process feed changes in volume, temperature, or composition
- Notification that analyzers, dampers, valves are in manual, or being worked on
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Indication of Possible Flooding

Hazy firebox

After adjustment
Fuel Rich vs. Clean Firebox

Heater flooded, fuel rich firebox

Clear firebox, burners adjusted
Fuel Rich vs. Clean Firebox

- Flooded heater, hazy firebox
- Heater after adjustment
Fuel Rich Firebox

Note this tube has fallen & is in front of tube below
Fuel Rich vs. Clean Firebox

Long tailing cloudy flames, haze visible in the firebox

Clear firebox, no haze
Outline

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• Indication

• **Response**
• Examples
• Prevention
General Response

What to do:

• Reduce fuel flow rate until pulsing stops & flooding is corrected
If flames become unstable…
Slowly cut back on the fuel
General Response

What not to do:

• Do not go to heater
• Do not adjust stack damper or burner air registers
• Do not shut down heater
Response – Outside Operators

• DO NOT GO TO HEATER

• Evacuate any personnel in vicinity

• Do not open sight doors (added air could cause fire or explosion)

• Radio to control room to advise
Response – Inside Operators

• Notify outside operators to stay clear of heater & to get any other personnel out of the area

• Slowly cut back on fuel until flooding is over (suitable excess O2 measured)

• If burners flame out, cut fuel to heater
Outline

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- Indication
- Response

- Examples
- Prevention
Hydrotreater Incident #1

What Happened

• Heater tripped (flame scanner problems)
• Problems relighting
• Block valves manually bypassed (w/o using proper procedures) due to dropping heater temperatures
• Multiple relights attempted, purge steam permissive already satisfied so no purge on last attempt
• Heater detonated
Hydrotreater Incident #2

Analysis

• Original trip caused by false loss of flame due to pilot flames blocking sight of main flames

• Subsequent loss of flame shutdowns were real; heater box was rich in fuel gas & flame was snuffed out

Results

• No mechanical damage

• No one injured
Hydrotreater Incident #3

During start up, bypass around heater fireman was open. Excess volume of fuel gas pushed heater outlet temperature well above target. Burners were cut off. When they were put back on, fuel gas (due to open bypass) rushed into heater & detonated.
Heater Incident

- Primary gas tips plugged, excess oxygen low, added air instead of reducing fuel, resulting in heater incident
- Vacuum heater’s burner tips fouled even after steam-out: rock inside gas tip
Heater Incident

- Incident occurred on hot oil heater
- Significant damage sustained to heater side walls
- No injuries or loss of containment from process
- Root Cause:
  - Unburned fuel accumulated in heater, most likely due to flooding or flameout of #6 burner
  - Fuel accumulation was ignited during attempt to light a burner #8
Heater Flooding Incident

- Heater started up after routine shutdown
- As burners brought on, not enough air available causing heater to huff
- Air registers opened providing air that ignited flooded heater
Fired Heater Flooding

Indications of flooding include:

• Low O2 (<0.5%) and/or high combustibles (>1000 ppm) are first indication of a potential firebox flooding situation

• Rapid drop in coil outlet temperatures and/or firebox bridgwall temperatures
  • Drop in COT causes firing rate to increase due to closed loop control & worsens flooding condition of heater

• Loud rhythmic “whoosh” sound or vibration

• Pulsating / unsteady flames

• Local draft gauge swinging widely

• Hazy appearance in firebox or smoke from stack (during severe bogging)
Fired Heater Flooding

Causes for fired heaters being prone to flooding include:

- Large swings in fired duty on a regular basis
- Significant variances in fuel heating value
- Air registers or stack damper are fixed or manually operated
- Heater is air limited
- Delayed O2 analyzer response times
- Heater has exhibited signs of severe flooding in the past
Fired Heater Flooding Response

**Do**
- Immediately reduce fuel input
- Personnel should stay away from immediate fired heater area if flooding is suspected

**Don’t**
- Do not automatically **trip** heater in this situation
  - Sudden removal of all fuel from a rich firebox may result in a flammable mixture that could auto-ignite
- Do not take any steps that may increase air into firebox, e.g. damper adjustments, opening observation doors, etc.
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Flooding Prevention

- Adjust heater operation before major fuel changes
- Maintain instruments: O2, CO, draft, etc.
- Communicate with maintenance, especially about any instruments out of service/not working
- Include anti-bogging controls in heater control scheme
Flooding Prevention

Consider:

- Adding red flashing light at heater during flooding incident or high CO
- Adding Burner Management Systems (BMS) to shut down heater during flame outs
- Adding alarms for:
  - High fuel pressure
  - Low combustion air flow / High combustibles
  - Sudden drop in bridgeway wall temperatures
- Reviewing existing flooding procedures
Conclusions/Recommendations

- Heater flooding is a very serious condition that must be dealt with properly
- Procedures must be in place & followed
- Training is critical
- Equipment must be properly maintained