Successful Operation of SRU with Condenser(s) Bypassed

2022 Brimstone Sulfur Symposium - Vail

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Overview

- Background info on Lost Cabin Gas Plant
- Description of events that led to:
  - Initially running without the #3 sulfur condenser (shell side water out of service)
  - Switch to running without the #4 sulfur condenser
- High level data for both operating modes
- Discuss turnaround findings
- Final conclusions/questions

Background-Lost Cabin Gas Plant

- Located in central Wyoming
- Process gas from the Madden Deep Formation
- 3 Trains built 1995-2002
  - Inlet cooling
  - Selexol unit for H_2S and CO_2 removal
  - Modified Claus with SCOT unit

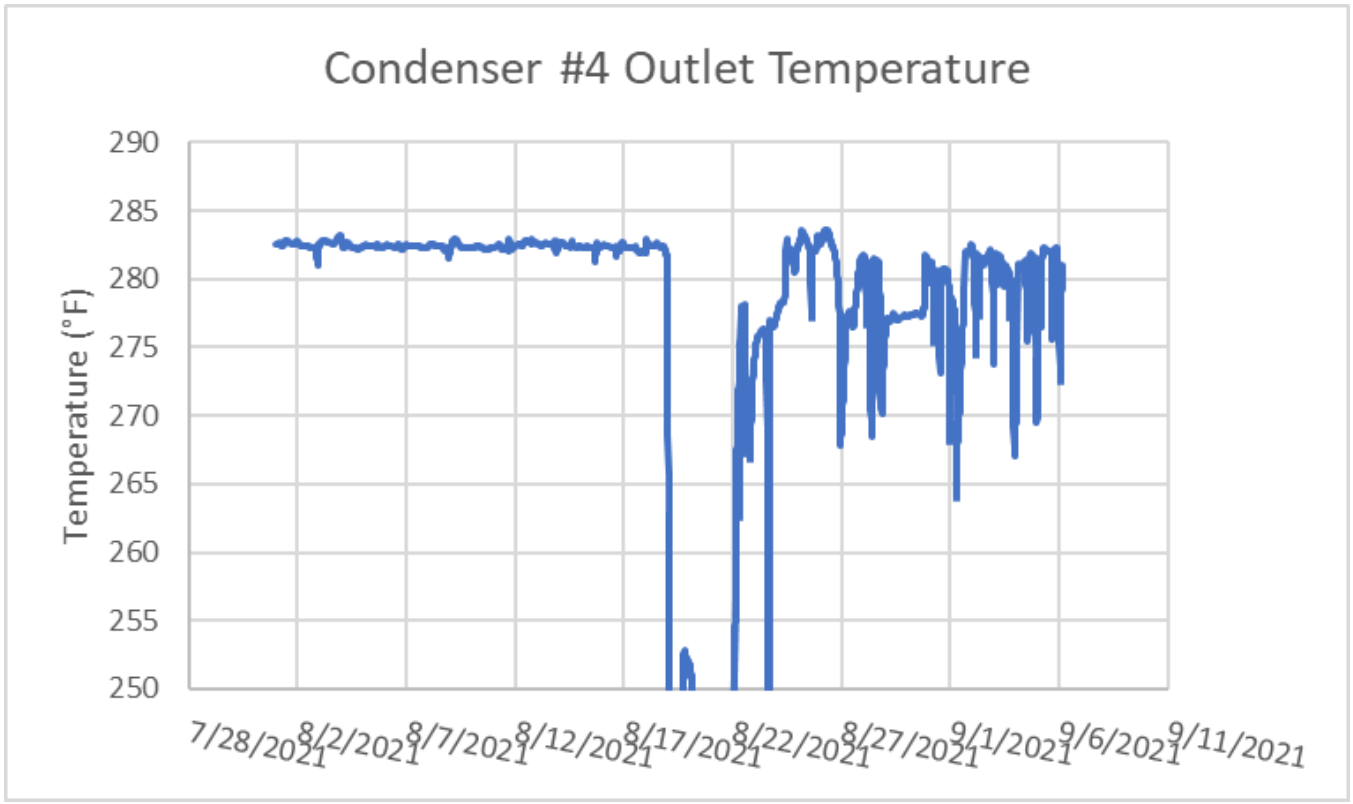
- Trains 1 & 2 inlet capacity of 65 mmscfd (300 Lt/d sulfur)
- Train 3 inlet capacity of 180 mmscfd (900 Lt/d sulfur)
- Train 1 decommissioned in 2017
- Currently process 210 mmscd inlet gas, ~1000 Lt/d

Initial Condenser Leak

- Fire occurred in the Train 3 Selexol unit in Dec. 2018
- 2 year rebuild; unit was restarted in Jan. 2021
- During restart activities, significant tube leaks discovered in the #3 condenser
  - Required plugging of 215/1600 tubes

2nd Condenser Leak

- Unit was online from Feb. 2021-Aug. 2021
- Power outage in August caused the unit to be down for several days
- After coming back online, issues with the #4 above ground sulfur seal not flowing
- Also observed periodic drops in the vapor outlet temperature of #4 condenser
- Indicated potential tube leak in the condenser

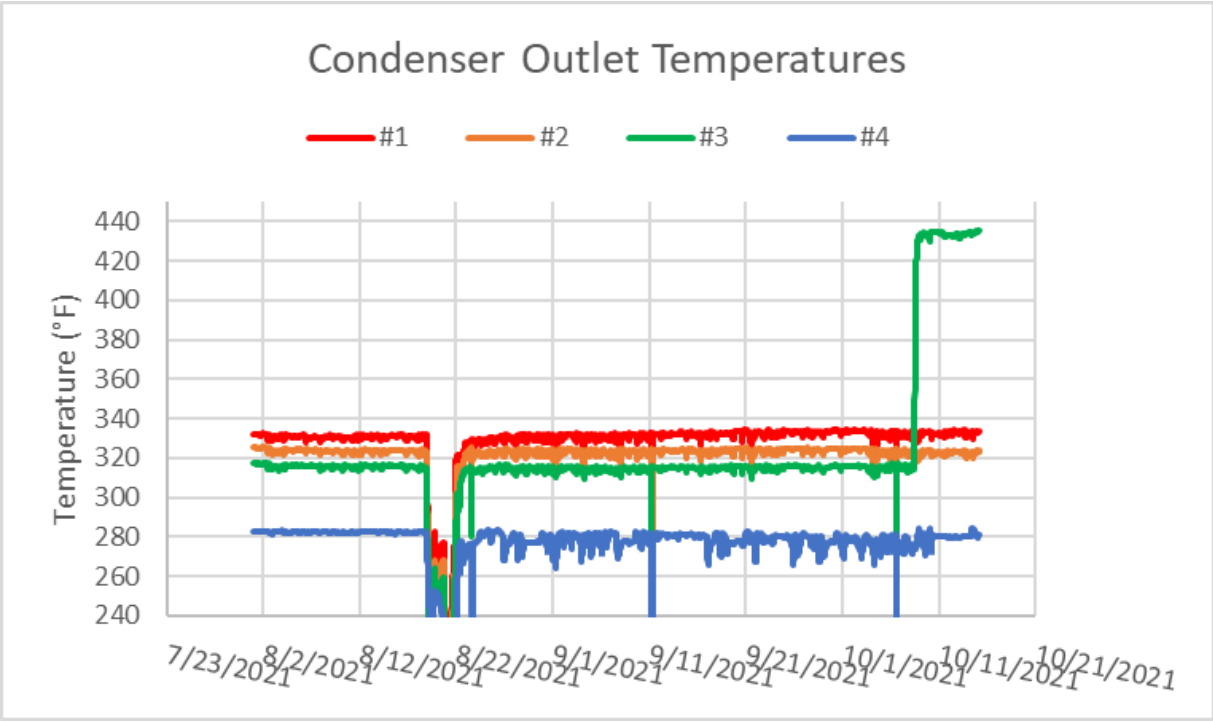


2nd Condenser Leak

- Issue continued to get worse; discussion around shutting down unit to clean and plug tubes in Oct. 2021
  - 10-14 day downtime, loss of ~100 mmscf/day of sales gas @ ~$5.50/mmBTU, 700 Lt/d of sulfur
  - ~$750K contractor cost to clean, hydro, plug #4 & #3 condenser tubes
- Also evaluated and developed procedure for taking the condenser shell side water out of service
  - Maintain steam pressure on shell side
  - Remove water leak at expense of efficiency loss
- Over the weekend, emergency MOC executed to take the *#3 condenser* out of service
  - Still in troubleshooting phase, final effort prior to shutting down unit
  - Technical evaluation previously done for taking #3 condenser out of service

Decision to Continue Running

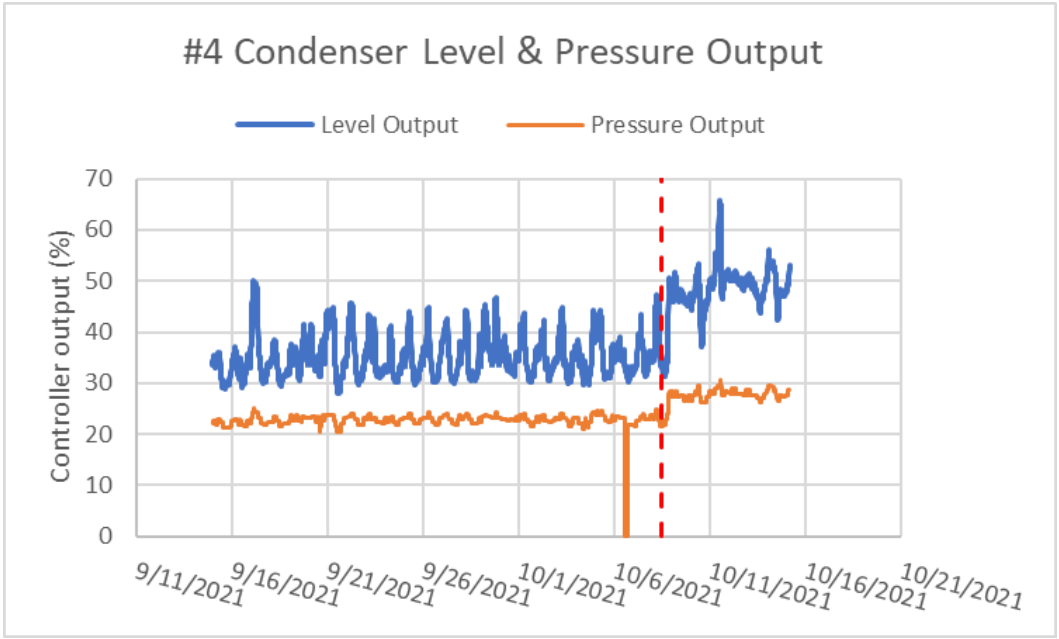
- Initially seemed to alleviate issue
  - Outlet temperature had stabilized
  - Load shifted to #4 condenser
  - Continuous flow of good quality sulfur

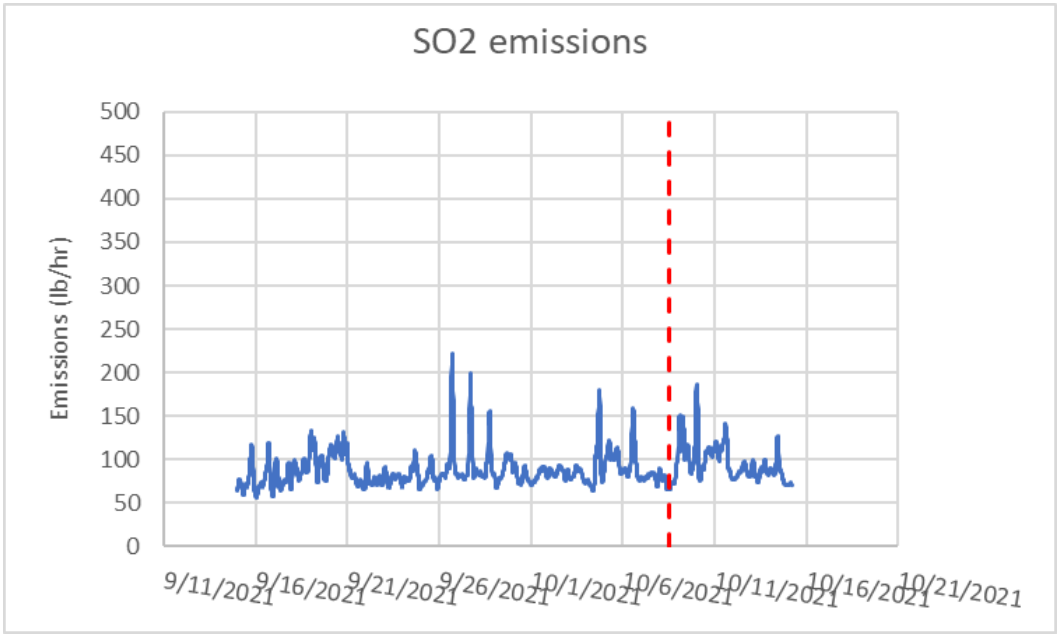


(video)

Operating Data with #3 Condenser Bypassed

- Level and steam control for #4 condenser also indicated load shifted
- No significant impact to SCOT. Emissions were stable
- Slight increase to normalized pressure
- At maximum well delivery, only needed to operate 75-80% design capacity





Issues Resumed

- Within ~1-2 weeks, continued to have similar issues, evidence of water
- Tested #3 condenser; shell side holding steam pressure
- Could not put #3 condenser water back in service with unit online

(video)

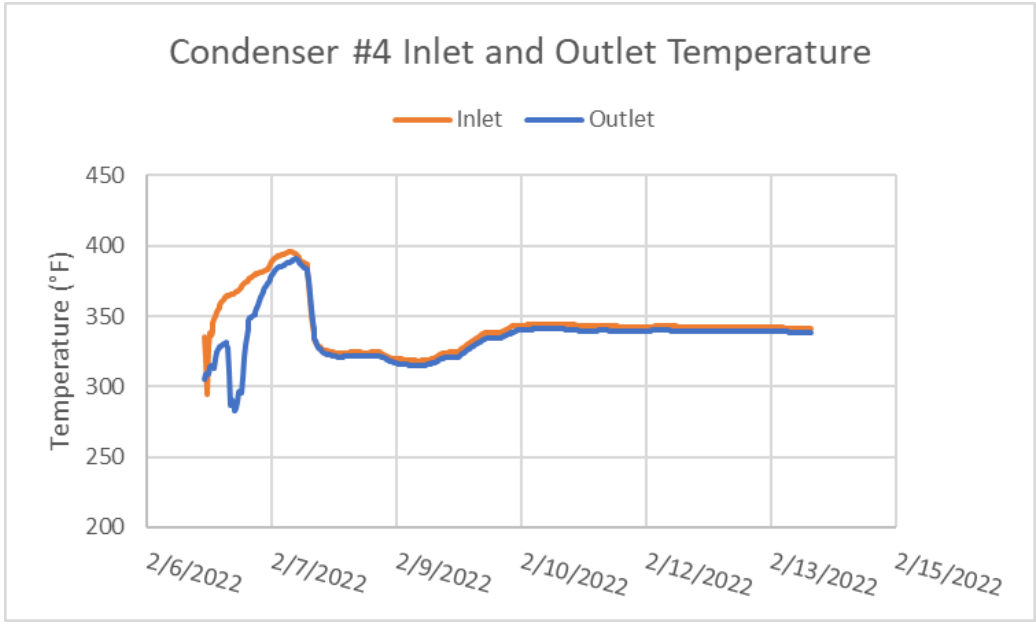
(video)

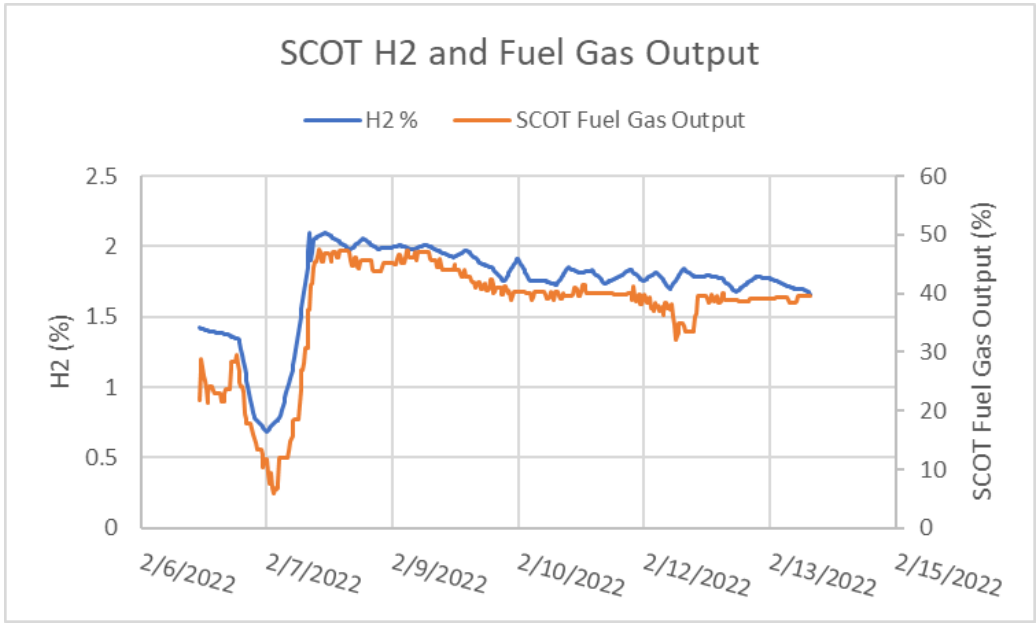
Issues Resumed

- Decided to continue in current operation mode
  - Sulfur seal has jacketed bypass, allowing for manual draining
  - Sulfur pit ~16 hr residence time, remaining water should boil off
  - Corrosion should be limited if temperatures are maintained
  - Inspect pit during turnaround
  - Developed procedure to ‘swap’ if opportunity arose

Bypassing #4 Condenser: Initial Operating Conditions

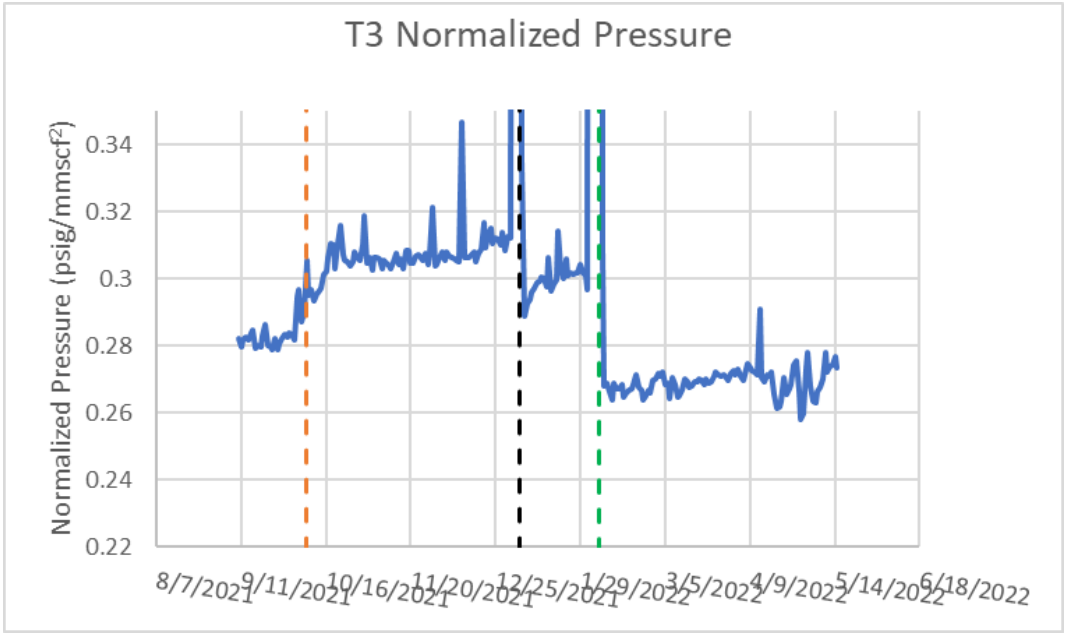
- Executed condenser swap in early February
- Initially kept #3 reheat 390 °F
  - Low SCOT fuel gas output and H_2
- Modified:
  - Reactor inlet 530 -> 550 °F
  - Fuel gas ratio: 80 -> 72%
- Briefly lowered #3 reheat to 320 °F
  - Concern about sub-dewpoint operation
- Final conditions:
  - Reheat at 340 °F
  - SCOT reactor 545 °F

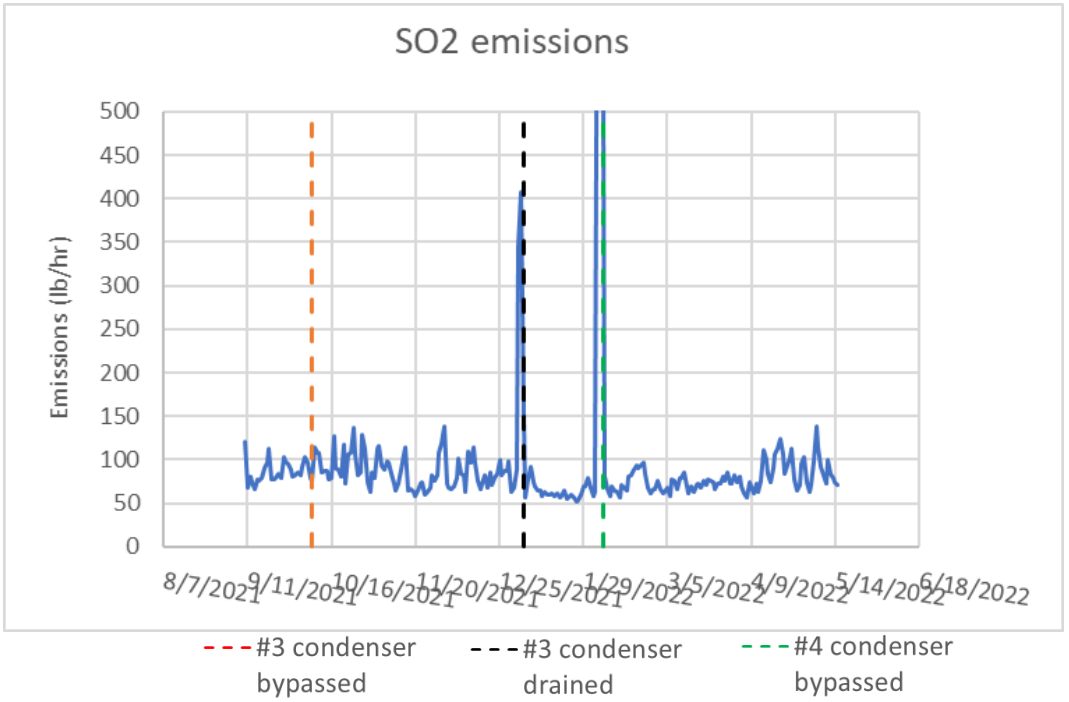




Operating Data: #4 Condenser Bypassed

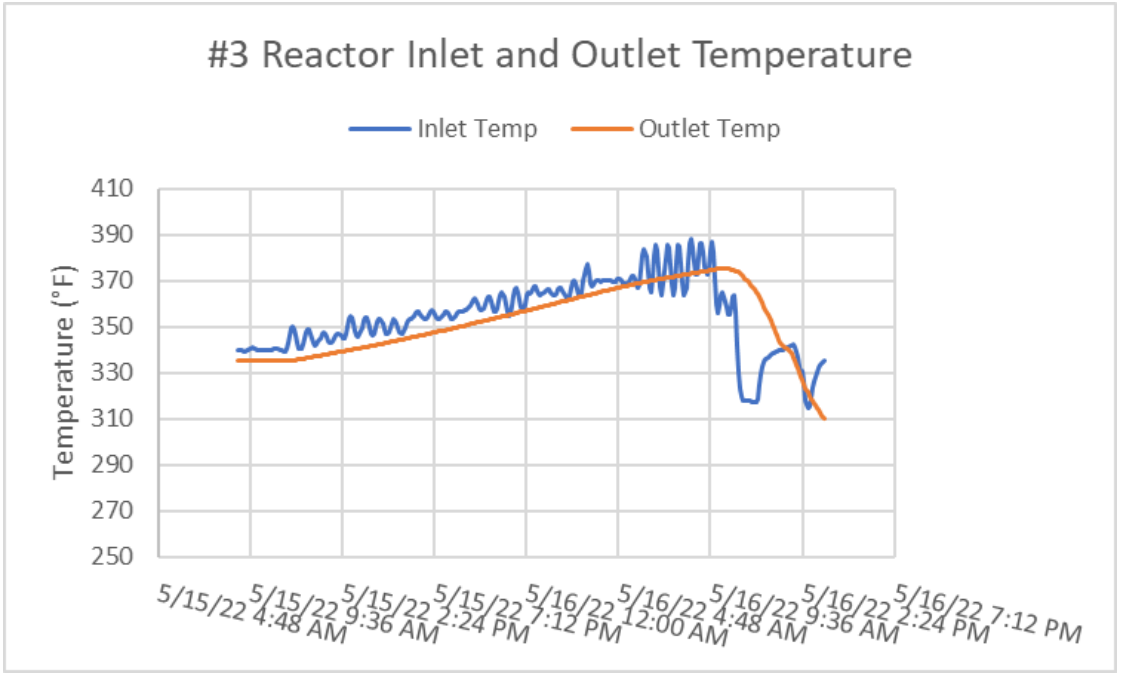
- Unit lined out well
  - Minimal issues with #3 rundown
  - Small amount of sulfur condensed in #4
  - Normalized pressure improved
    - Higher throughput (>90% nameplate) during other train's turnaround
  - No significant impact to SO_2 emissions

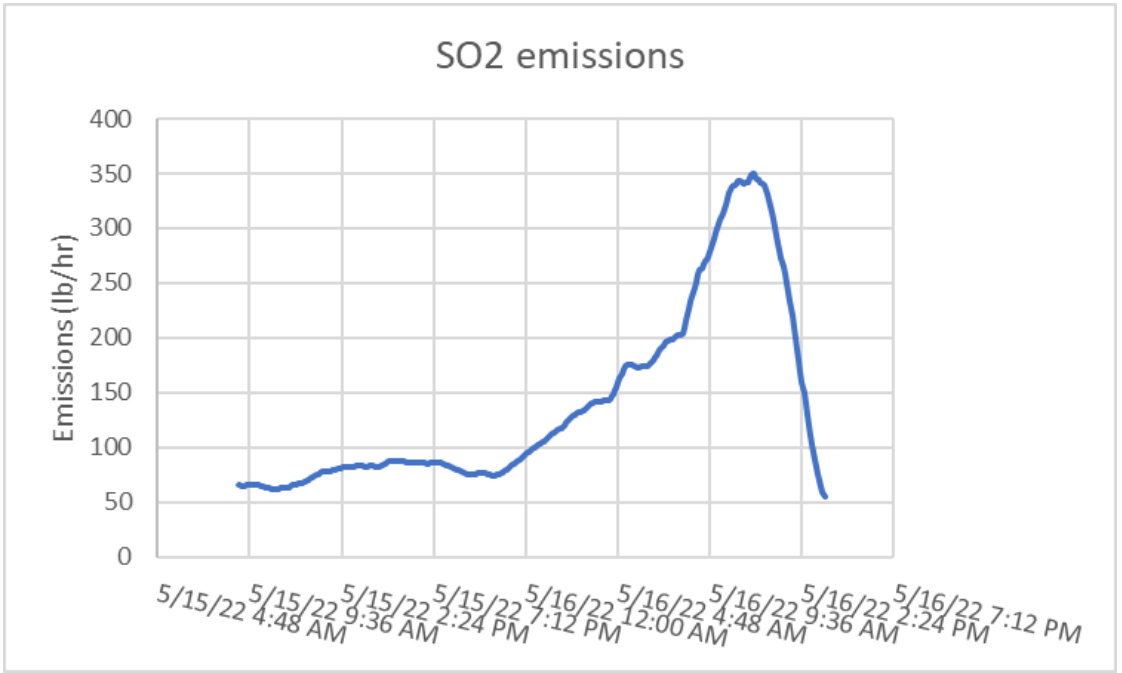




Sulfur Strip

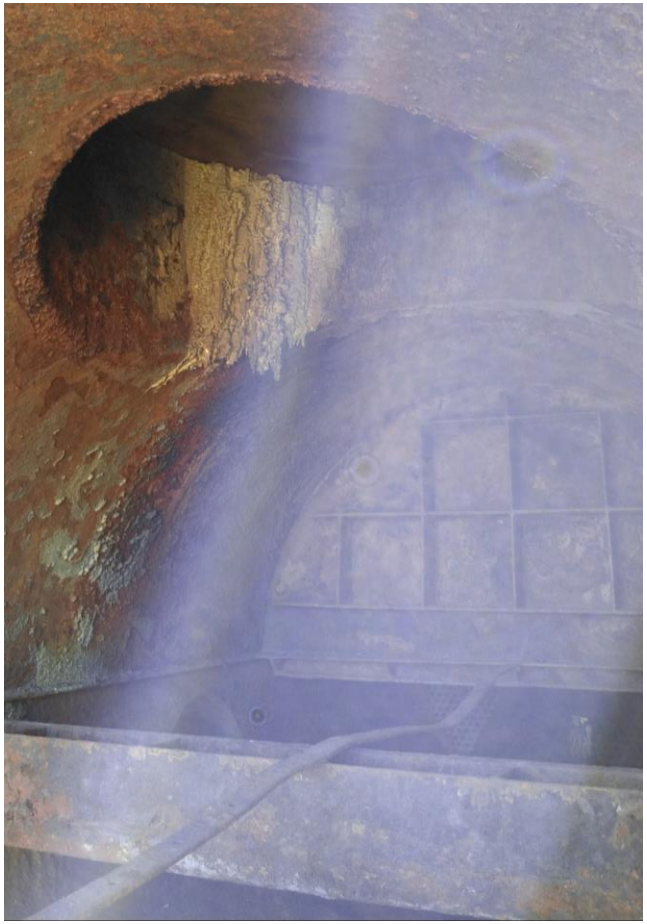
- Prior to T/A, concern over sulfur deposition in catalyst bed and outlet line
  - Plugging of reactor bed during cool down
  - Emissions during start up
- Performed sulfur strip prior to S/D
- Worked with state on potential for increased emissions during start up





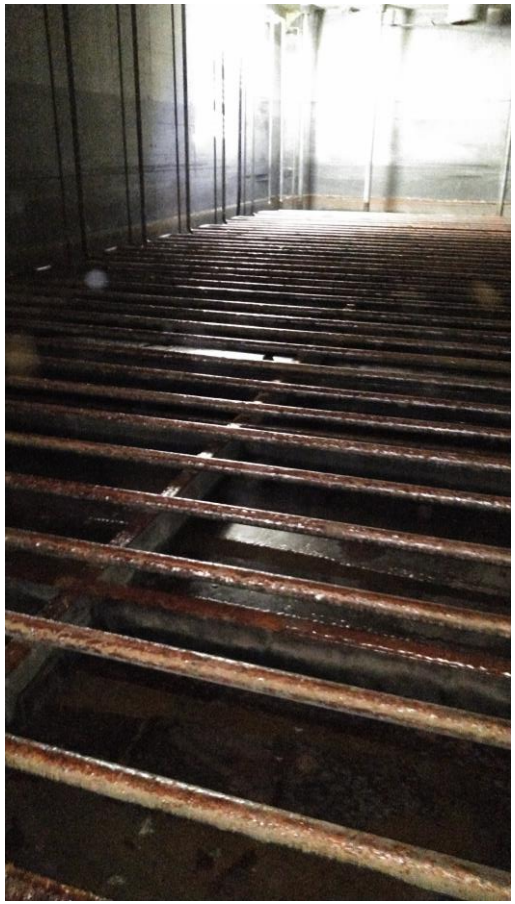
Turnaround Findings: #4 Condenser

- #4 condenser had 36 leaking tubes in bottom rows
  - Decided to plug entire bottom 6 rows
- Sulfur deposition observed on outlet nozzle



Turnaround Findings: Sulfur Pit

- Issues associated with inspecting sulfur pit
  - Hadn't been drained in 20 years. FeS smoldering- SO_2 off gas
  - Briefly put water in pit to allow for entry
- Findings
  - Sludge near inlet
  - Otherwise, no issues with steam coils or concrete



Summary

- Able to avoid costly shutdown and make it to planned turnaround
- High level findings
  - Running with leaking condenser
    - No major impact to equipment after several months of running in this mode
    - Above ground sulfur seals-need jacketed bypass
  - Running with condenser bypassed
    - Successfully operated with 3/4 condensers at >90% throughput capacity
    - Potential to still have sulfur condensing
    - Further complications with #4 condenser offline
      - SCOT unit H_2 generation
      - Sulfur deposition and emissions

Questions