INTERRUPTED DRUM INCIDENT: A REFINER'S REPORT

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INTRODUCTION

Incident background:

- Two-drum coker with four-pass heater
  - Produces sponge coke
- Refinery-wide loss of electrical power and steam

Topics:

- Interrupted drum with plugged inlet line
- Plugged heater

TIMELINE

4-Apr-2015

1:12 AM – refinery-wide electrical power outage

- Filling coke drum had two hours remaining until switch
- Feed pump tripped offline and velocity steam valves went to 100%.

  – Steam meters top at 500 lb/hr/pass (estimate 1/3 normal drum steam)

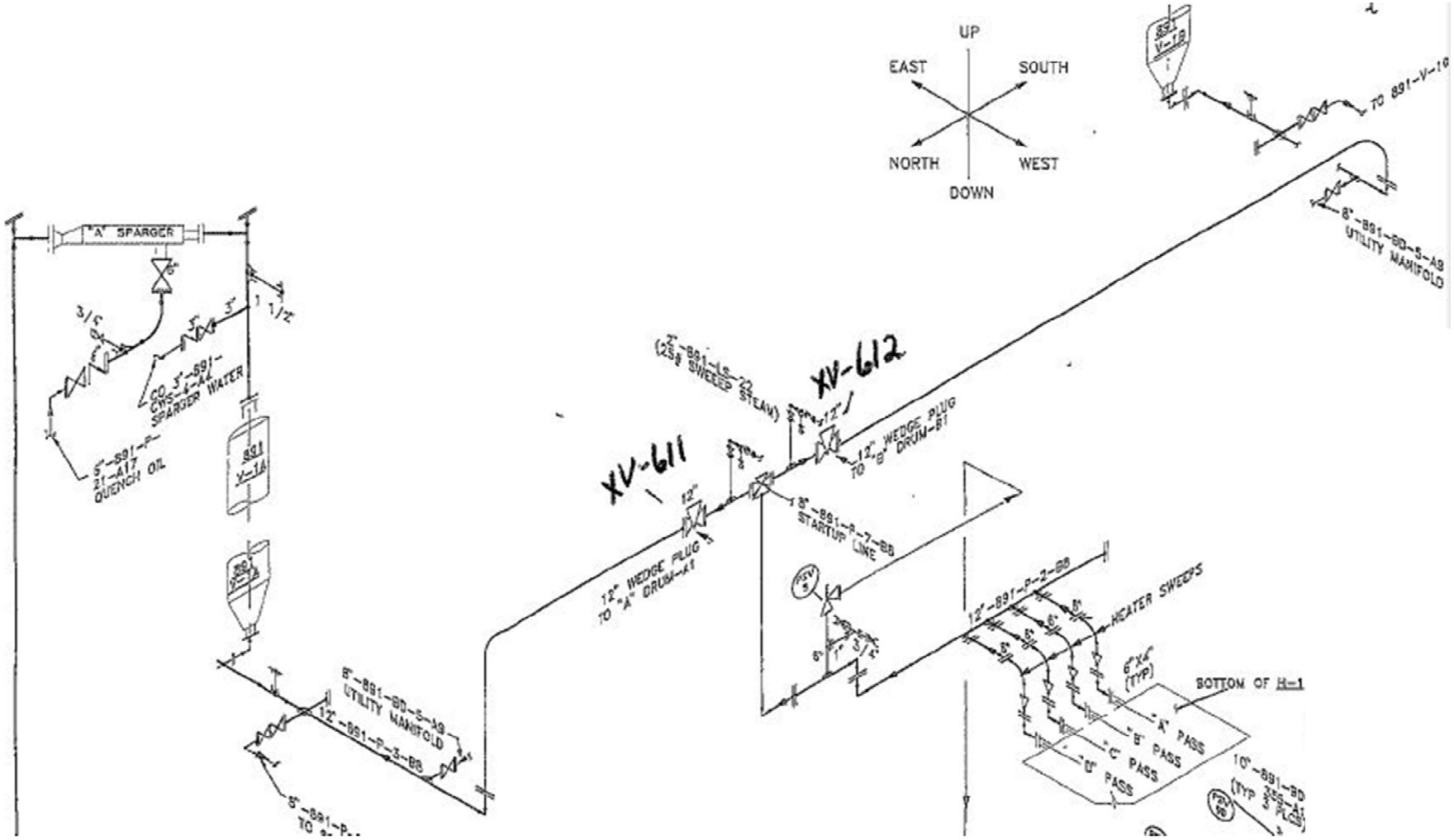
1:22 AM – Boilers started to trip and steam header pressure begins to slump

2:23 AM – Coker steam flow rapidly declining – temperature on the drum inlet begins to rise, indicating the back flow of some resid from the drum.

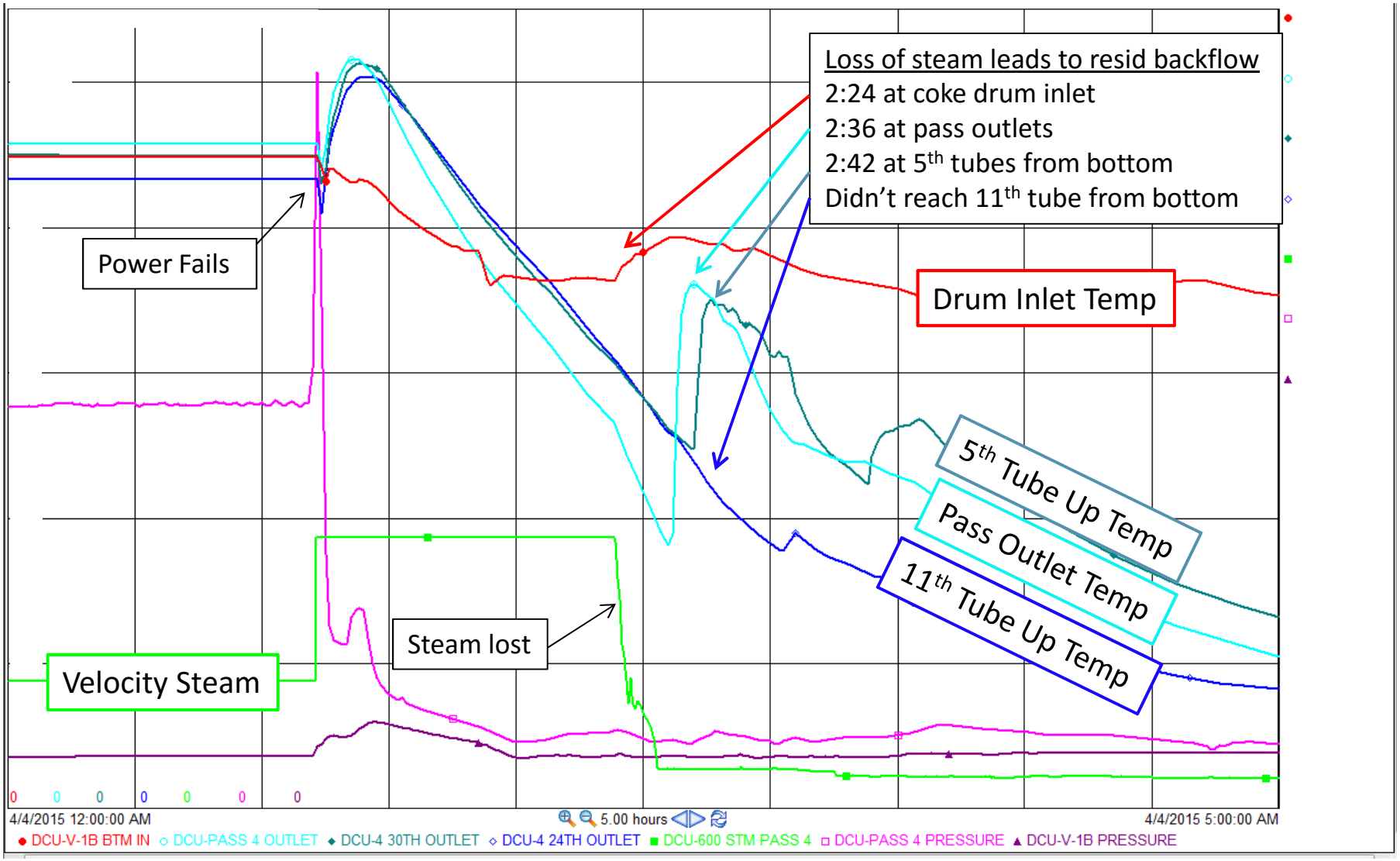
2:33 AM – Steam is lost completely – heater process temperatures indicate that resid flowed back into the heater until 2:42 AM.

10:42 PM – steam is restored – unable to get steam into bottom of coke drum or through heater.

TRANSFER LINE - HEATER TO DRUMS



TIMELINE


Loss of steam leads to resid backflow
2:24 at coke drum inlet
2:36 at pass outlets
2:42 at 5th tubes from bottom
Didn't reach 11th tube from bottom
Power Fails
Drum Inlet Temp
5th Tube Up Temp
Pass Outlet Temp
11th Tube Up Temp
Steam lost
Velocity Steam
4/4/2015 12:00:00 AM
5.00 hours
4/4/2015 5:00:00 AM
DCU-V-1B BTM IN
DCU-PASS 4 OUTLET
DCU-4 30TH OUTLET
DCU-4 24TH OUTLET
DCU-600 STM PASS 4
DCU-PASS 4 PRESSURE
DCU-V-1B PRESSURE

SAFETY FIRST

Situation once steam and power restored:

- Interrupted drum - near end of cycle
- Drum inlet and heater plugged

Plan was developed and revised over time

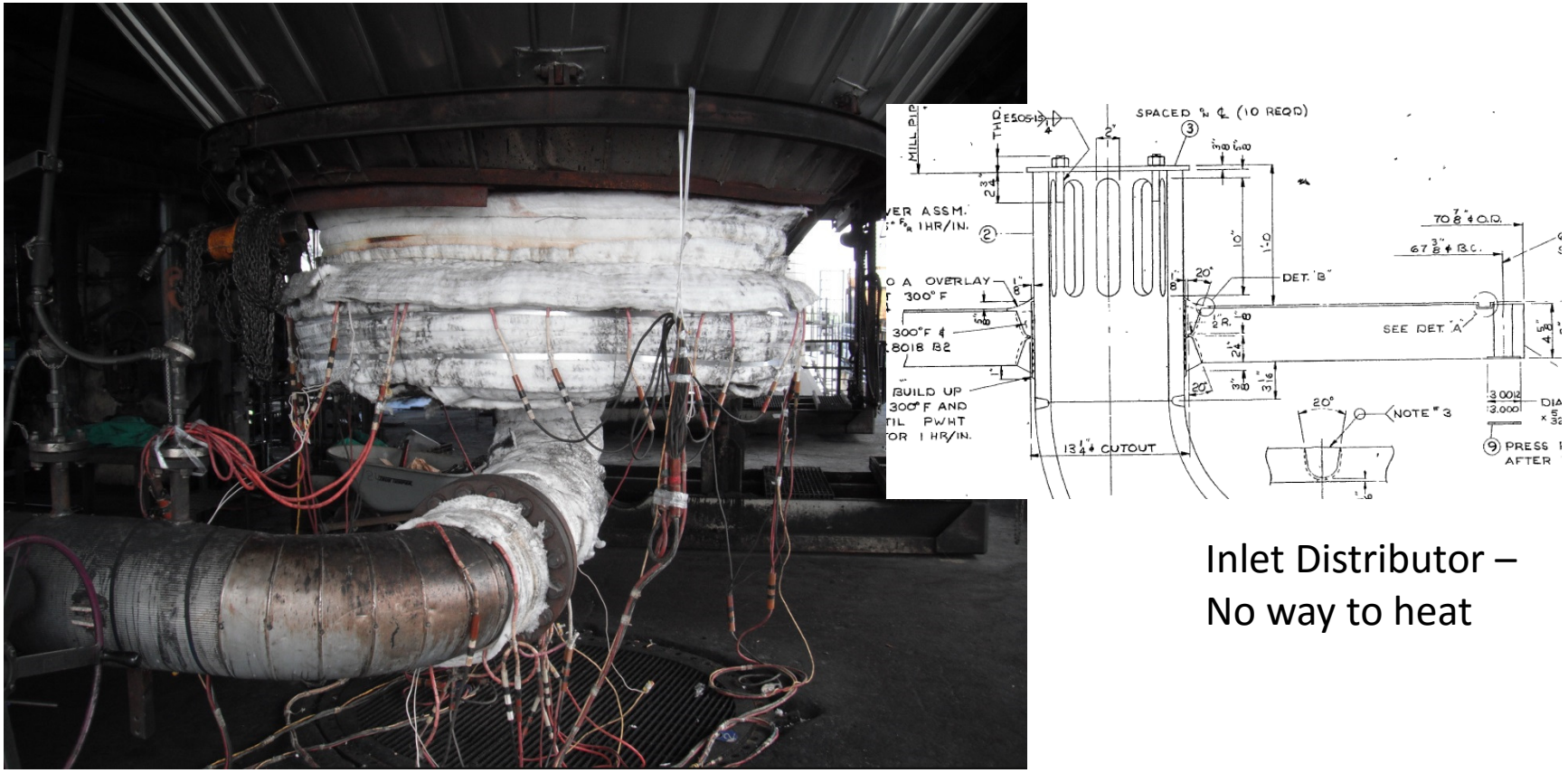
- Multi-functional team
- Input from many sources
  - Refinery staff, other Phillips 66 refineries, Phillips 66 HQ, industry peers
- Refinery Leadership Team reviews
- Refinery Risk Reviews – RLT, ops, crafts, safety, technical
- Phillips 66 peer review – HQ plus refinery managers from 2 other sites.

ATTEMPTS TO GET FLOW INTO BOTTOM OF COKE DRUM

- Tried to get into bottom of drum for 5 days without success
  - Once steam was restored tried it via the normal line-up
  - Tried alternating water and steam, hammering the line as is typically done with a coke drum plugged during normal operations
  - Pressured inlet with higher pressure steam
  - Used high pressure portable pumps to attempt to push water into drum
  - In conjunction with above, tried heating line with heat treatment pads to 450F

Decision: Top quench and develop means to lower head remotely

HEATING DRUM INLET



Inlet Distributor –
No way to heat

TOP QUENCH

- Slowly top quenched drum
  - Half rate of normal quench ramp
- Filled to the middle level detector
  - Covers the coke bed.
- Success of quench indicated by:
  - During fill had to put fuel gas into drum to avoid vacuum
  - Metered water in – used more than expected to hit middle level detector
    - Unable to do an energy or water balance on steam from the drum condensing in blowdown due to lack of functioning instruments
  - Pressure and temperatures indicated a good quench
  - Water held at the middle level detector for a couple of days without loss of level
- With drum full of water, tried to drain and pressure drain to the normal drain line. This was unsuccessful, as expected.

Top quench was successful

MORE SAFETY

- Why this was not an Anacortes situation
  - Filling coke drum had two hours remaining until switch
    - Large coke bed well established
  - The feed pumps and heater tripped at loss of power
    - Limited volume of un-heated resid
  - Velocity steam through drum for one hour (1/3 rate of normal drum steam)
    - Velocity steam pushed most of resid into drum
    - No gas oil quench or antifoam after power failure
  - The top quench water boiled and created a lot of steam stripping
  - Sponge coke produced is very porous & easy to quench
  - A higher than normal water volume added with no level change for days

Primary concern: Hot water exposure upon unheading, not hot resid or hydrocarbon. But plan for any of these.

UNHEADING

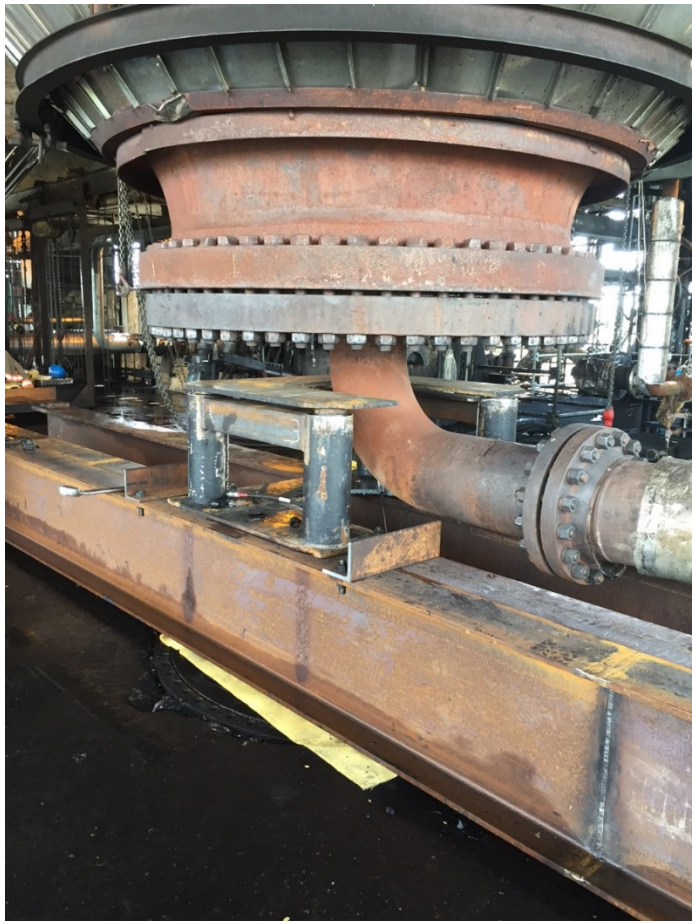
- Existing manual unheading not well suited to this situation
- Installed a temporary hydraulic jack system
  - System to hold bottom head while bolts removed and remotely lower head
    - Supported the force from the drum contents plus gasket sealing (140 tons total).
  - Lifting table containing four 50 ton hydraulic rams
  - Lifting table set on temporary beams
    - span 30 feet between the major beams of the coker structure
  - Due to spacing the system was could only lower the bottom head about 10 inches
  - Four long bolts installed in head as back up to lifting device
  - Successfully tested the system on the sister drum full of water to ensure effectiveness of procedure and equipment

UNHEADING

Existing head carriage does not have sufficient capacity to support head and maintain seal

Beams and lifting table set up under empty sister coke drum

TEMPORARY SYSTEM



Lifting table. Each of the legs contains a 50 ton hydraulic ram

Test on water-filled sister drum. Device held full load with excellent control of hydraulics.

UNHEADING

- Precautions for bottom head removal
  - Exclusion zone to keep everyone at a safe distance (on the order of 300 feet)
  - Only necessary personnel inside exclusion zone
  - Bunker gear
  - Emergency response ready
  - Plywood barriers on the unit side of the unheading deck
  - Elevator above unheading deck
- Vented drum – nothing unusual observed – and left open.
- With top water on, removed top head and left open.
- Probed coke bed with drill stem – nothing unusual
- Hydraulic jack system applied full force for 30 minutes to confirm hydraulics ok

UNHEADING

- Removed bolts from bottom head,
  - Except the four long bolts set to allow ~10-inch gap.
- The temporary hydraulic device lowered the bottom head
  - Control station ~170 feet away.
  - It was on the bridge crane with easy egress along the rail cat walk.
- Bottom head was lowered to the 10-inch gap.
  - The bottom head lowered with a coke/pitch plug the same diameter as the bottom head, filling the 10-inch gap.
  - After a few minutes water began to drain around the plug. It was not a large rush of water and it took several hours for the drum to drain.
- Overnight, re-quenched the drum with water, and drained again.

PILOT CUT

17-Apr-2015 Noon – Pilot hole cut

- Due to uncertainty that the drum had completely drained of hot water, we cut the pilot hole through the 10-inch gap (lots of discussion on this)
- Pilot took 20-25 minutes vs. 15-20 minutes normally.
- The last few feet went a little slow until the plug sitting on the head was broken up and the pilot cuttings could push out.
- Coke and water initially gushed out maybe 25-30 feet where it first broke through.
- After the initial wave, coke continued to come out pieces at a time.
- Then the coke lessened and it was mostly just water hitting the bottom head and spraying out with occasional chunks of coke.
- After a few minutes it was just water hitting the head and spraying out maybe as far as 40-50 feet at times.

FINISH

- After pilot cut, remotely pushed bottom head back in place with temporary device.
- Rebolted bottom head, but left a small gap
  - So that no coke or water would accumulate in the bottom of the drum to discharge when head re-lowered.
- Cleaned the mess on the unheading deck from drilling the pilot
- Temporary device removed
- Normal head cart used to lower the bottom head
- Drum cut normally – 19-Apr-2015

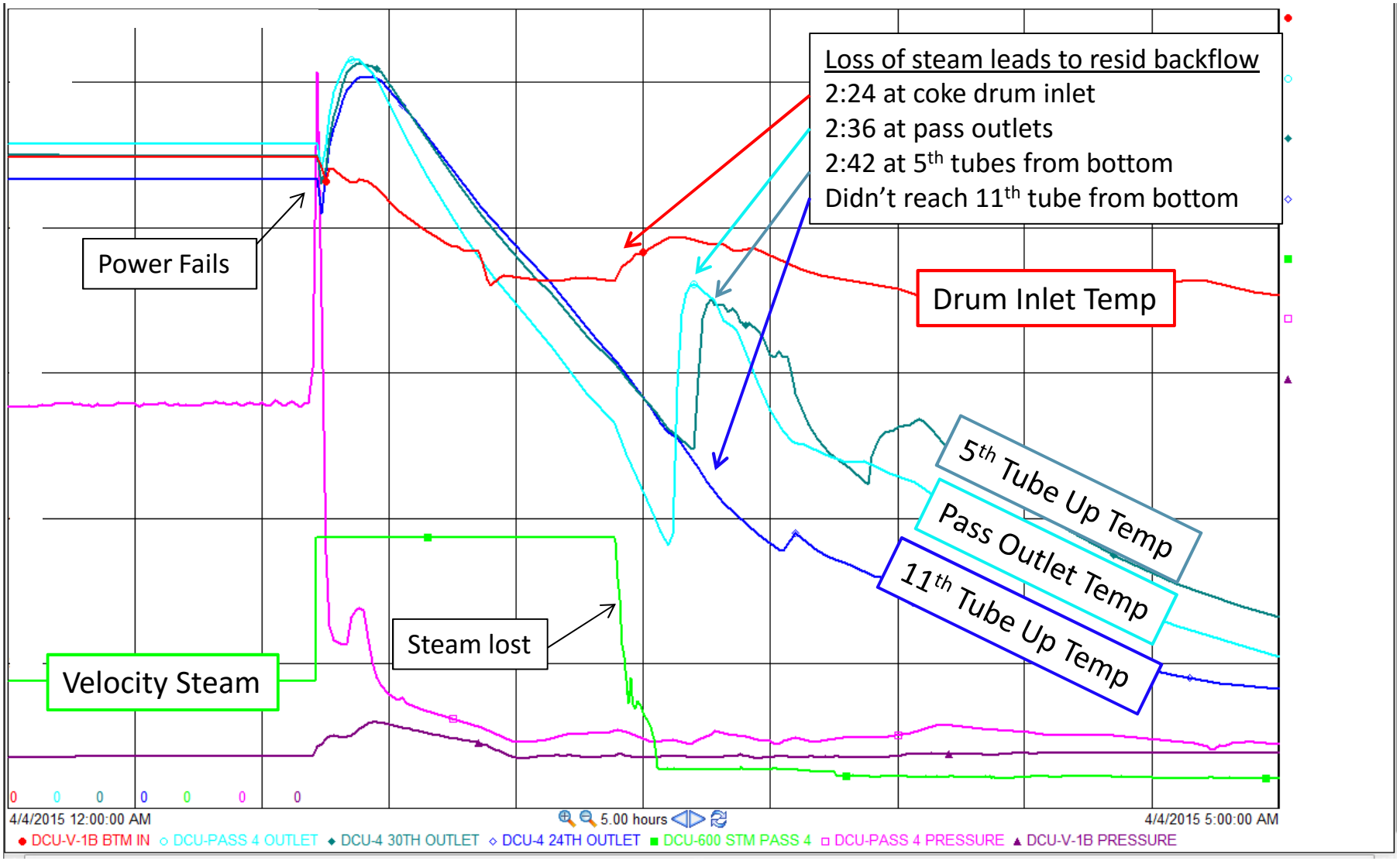
The drum was cleaned safely and with minimal potential personnel exposure to the drum contents.

WHAT COULD WE DO FOR THIS SCENARIO?

Identify back up fluid for injection into bottom of the drum if steam and quench water unavailable. Keep the inlet flow paths open into the coke drum.

- Firewater jump-over into the drum inlet (precautions)
- Local diesel powered water pump located in the coker
- Fuel gas instead of fire water.

HEATERS – REVISIT TIMELINE



ATTEMPTS TO GET FLOW THROUGH HEATER PASSES

Attempted to establish flow for 5 days:

- Heated all tubes above 350 deg F and pressured up all 4 passes to 600# with velocity steam.
- Wrapped the mule ears, pass outlets and transfer line with heating pads
- Eventually established steam flow through pass 1, but not passes 2, 3, or 4

Decision: Water drill passes 2, 3, and 4 to establish flow path.
Then pig all four passes. Clean transfer line.

PLUGGED HEADERS (AKA MULE EARS)

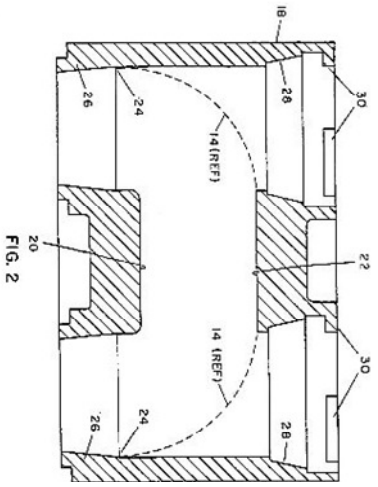
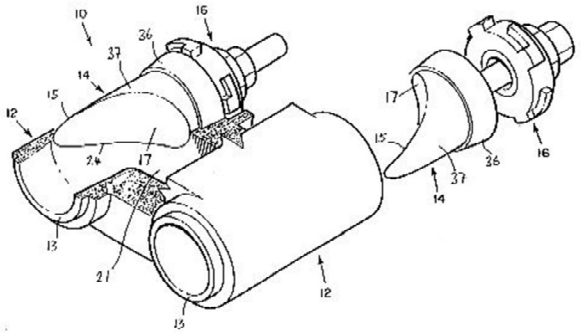


FIG. 2

FIG. 1



WHAT WE FOUND

- Material in bottom 8-10 tubes and first part of heater outlets
  - Coke in outlet piping through first elbow and a little ways up into vertical piping.
  - Coke layer in bottom few tubes
  - Viscous oil in next few tubes
- Not much material in transfer line and upper tubes
- Consistent with process TIs which showed back flow at pass outlet and 5th tube up from bottom, but not at 11th tube up from bottom.)

Theory

- Velocity steam appears to have pushed most of the contents of the transfer line and heater into the drum.
- When steam stopped, the remainder gravity flowed back to the low spot, the lowest heater tubes and outlet piping.

OPENED MULE EARS

Coke layer in bottom few tubes

Viscous oil in next few tubes

HEATER OUTLET PIPING

Coke in outlet piping through first elbow and a little ways up into vertical piping