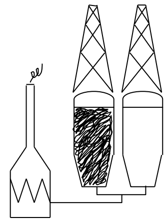
Delayed Coker
Cutting Derrick Collapse



Presented by Mitch Moloney of ExxonMobil

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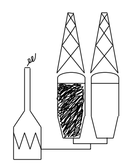
Delayed Coker Partial Derrick Collapse



Topics:

This Partial Derrick Collapse Event is very unique since it touches on many coke drum and coke cutting issues:

(1) Freeing Stuck Drill Stems

(2) Coke Drum Drill Stem Hoist System Design & Operation

(3) On-line Spalling Timing

(4) Furnace / Air-PreHeater Effects

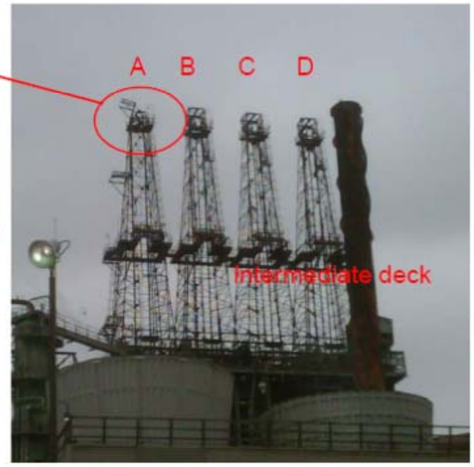
(5) Low-temperature Coke Drum Procedures

Special thanks to Dr Wolfgang Paul and Jay Jones of RuhrPumpen
and to Doug Adams and Andrew Worley of Flowserve
for their experiences and insights !!

Delayed Coker Partial Derrick Collapse

The Damage:

Sunday May 9, at approximately 9 AM the top 8-10 feet of the Coker derrick collapsed while cutting a drum and attempting to free a stuck drill stem.



In addition to the "A" drum, "B" drum was rendered inoperable since the two drums share a common bottom un-heading system. The "A" bottom head was un-headed at the time of the derrick failure.

Delayed Coker Partial Derrick Collapse

Event Summary:

On the night of May 8th, A drum was being decoked per normal procedures following a furnace spall and an abnormal event that fed a larger than normal amount of cold tar to the drum.

Operators were not able to raise and hold furnace COT's to cracking temperatures after putting a pass back on-oil after an on-line spall due to severe drum foaming; the drum was switched before a foamover occurred.

Normal steam strip, water quench and drain (~ 7hrs)

During the decoke process, the drill stem stuck several times but was freed.

Early the next morning, the drill stem stuck again, but attempts to remove it were unsuccessful.

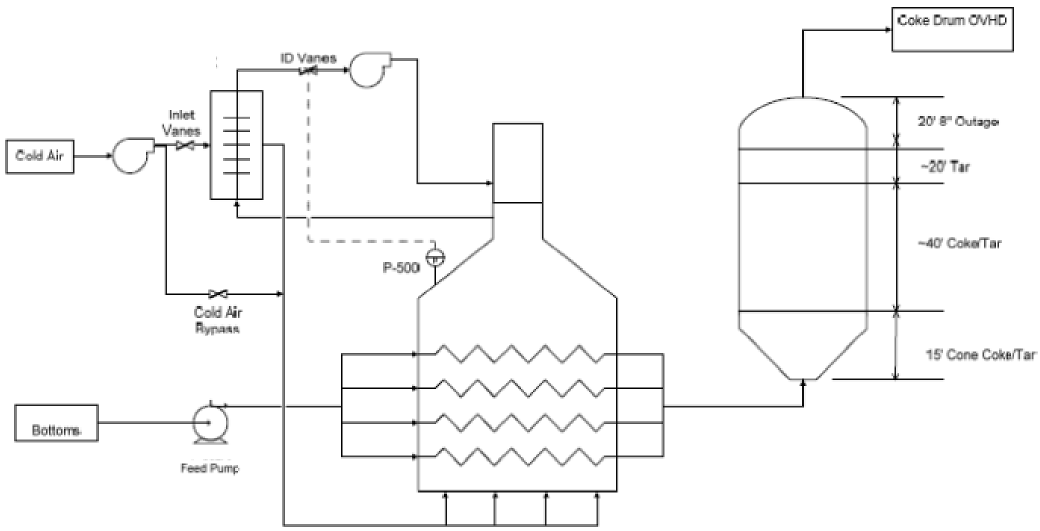
At approximately 7:30 AM, it was discovered that the top 8-10 feet of the Coker derrick had collapsed.

No injuries occurred during the event.
Significant Margin loss and Operating Expense were incurred

Delayed Coker Partial Derrick Collapse

Facilities Sketch:

Coker has 2 coking trains, each with an air-preheated furnace and coke drum pair



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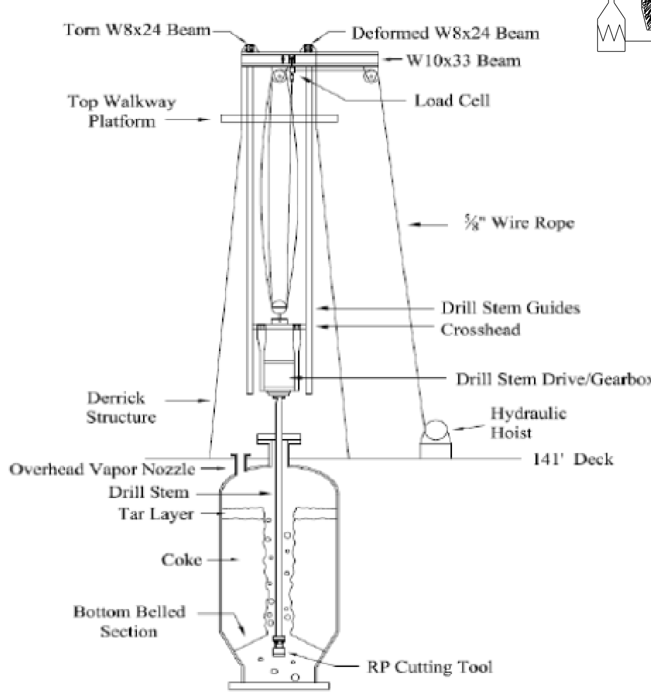
Cutting System Sketch:

CoFlexip Cutting Hoses
RuhrPumpen Manual Cutting Bit
RuhrPumpen Pneumatic rotary joint
Joy Winch 1970's version retrofit to hydraulics by Exxon

No Free-Fall Arrestor
No Cable Tension Readout
No Cutting Tool Elevation Readout



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Chronology:

May 8th 04:50 Furnace pass-3 out of service after coking in A-drum for ~6 hrs

11:30 After spalling was completed, steps were taken to begin cooling Furnace and return pass-3 to oil (all TMT's <950°F)

13:10 Cool down took 1.75 hr before pass returned to oil; normal is ~45 minutes. Cool down length was abnormally long due because ID Fan guide vanes did not reach typical 10% open value. The console supervisor controller was not aware that the ID guide vanes were 25% open.

14:10 After furnace COT's were at coking temperatures, the drum began to excessively foam due to partially-coked resid present from the abnormally long cool down.

14:30 To prevent a foam-over and protect the fractionator, the console supervisor switched to B-drum leaving ~260 tons of partially-coked resid in A-drum (~20' layer).

22:00 Following steaming, water quench and drain, the first pilot hole was successfully drilled. Upon coming up from the bottom the drill stem stuck ~ 55' from bottom. During next ~ 5 hours the drill bit was stuck and unstuck three different times (22:10 to 03.00)

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Chronology (cont'd):

May 9th 03:30 Started to cut the top layer going down. The top layer started to fall off in massive chucks and falling down through the pilot hole causing a partial restriction near the bottom of the drum. Per procedure, the cutter went down to try and clear obstructions out of pilot hole for future cutting. (03:30 - 04:00)

04:00 When the bit was down in the cone section of the drum, there was a major coke fall and shaking structure. At this point, could not go up or down, but bit was spinning slowly. The crosshead was about 5ft (1.5m) above the stops. The cutter tried to get the bit free from this point up until shift change. (04:00 to 06:00)

06:00 New shift came on and began trying to free the stuck bit. He was finally able to move it down, but not up. Cutter went to another job @ 07:00 and left drill about 1 inch off stops.

07:30 A Contractor noticed that the derrick structure looked abnormal at the top of the derrick; this is when the damage was found.

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Before

After

Delayed Coker Partial Derrick Collapse

Removal of Derrick - 1:

Delayed Coker Partial Derrick Collapse

Removal of Derrick - 2:

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Derrick Damage:

Torn W8 x 24 Beam

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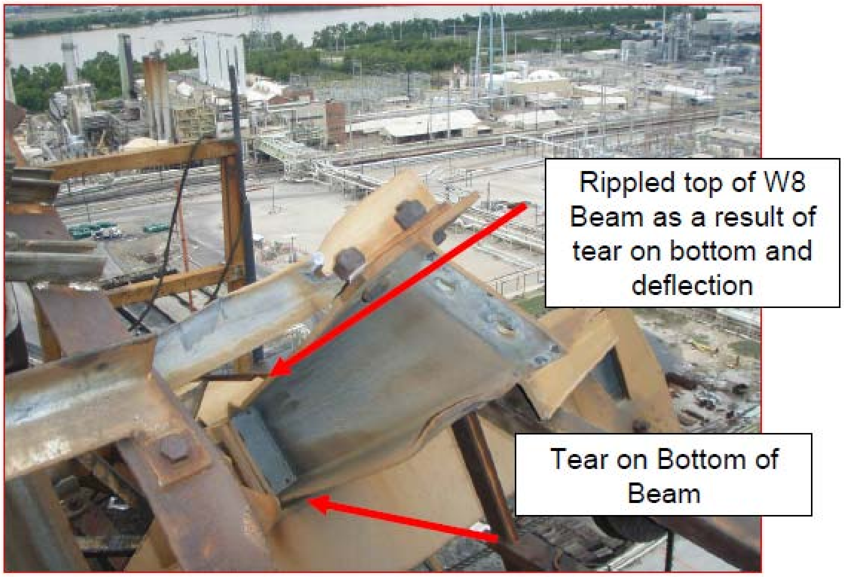
Derrick Damage:

Another Failed W8 x 24 Beam



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Collateral Damage:

Grating fell 85 ft (26 m) to cutting deck (141 deck)

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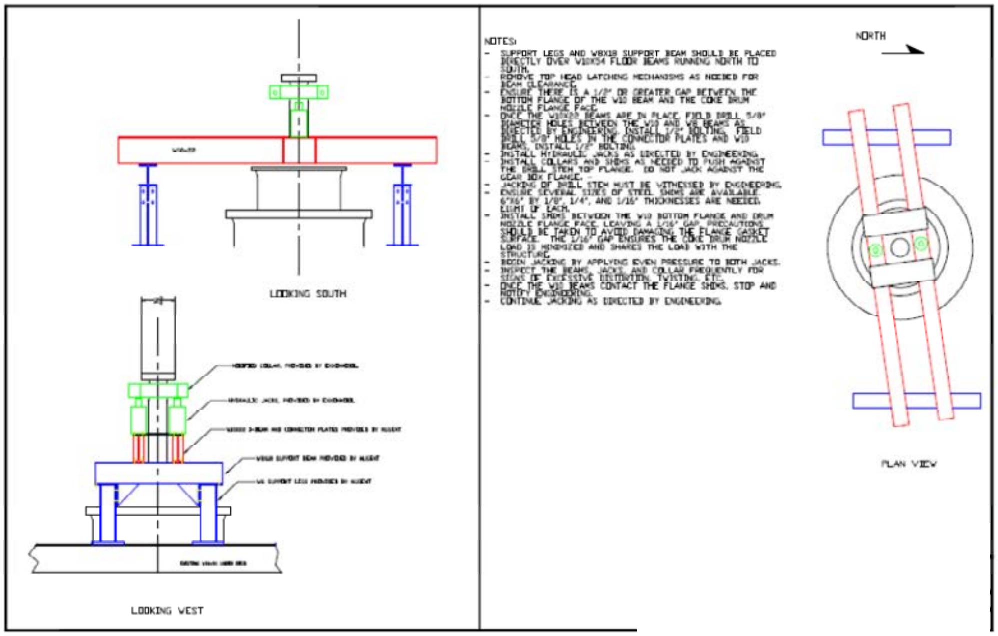
Hydraulic Jacks Arrangement (Unsuccessful):



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Hydraulic Jacks Photo:

- Two 30 ton jacks installed to lift drill stem
- Effort limited by top deck beam deflection limits & inability to supplement with winch pull, since the top derrick was destroyed.

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Hydraulic Jacks @ Other Sites:

Site-3 had installed a temporary (manual) winch to perform work and added additional beams and bolting to reinforce the upper derrick structure components to ensure they could handle the extra load that the winch was capable of applying.

Site-4 regularly uses two 100-ton (200,000 pounds of force, or 91,000 kg) hydraulic jacks to free stuck drill stems, with the winch functional.

This coker (Site-1) found that 60,000 lbs (27,000 kg) was maximum load the coke drum structure beams could support. And they did detect beam deflection on the structure when that force was applied.

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Freeing the Drill Stem @ Other Sites:

Site-2 “Have not had to use the "jacking device“, but were able to "float" the drill stem out of the drum."

Site-3 "We had to put the bottom head back on the drum a few times and float the stem out, but with oily coke, that can be tough…

Site-4 “We once had a stem stuck for 30 hrs. We now have jack-clamps. We have had broken cables previously, derrick intact :-) , and used a smaller diameter tugger cable through the sheaves to re-cable our winches. Once we had the new cable attached, we used it in conjunction with the jacking clamp, to unstick the Drill Stem.”

Site-5 - "We had a stuck drill stem due to a coke cave-in while boring a hole, allowing the soft coke to bury the drill stem. The drill stem was stuck for several days as we worked different strategies w/ no success. Finally we decided to ramp quench water through the feed pipe, as the cutter worked the winch. We were then successful. Having a slide valve in place helped greatly in reclosing the drum."

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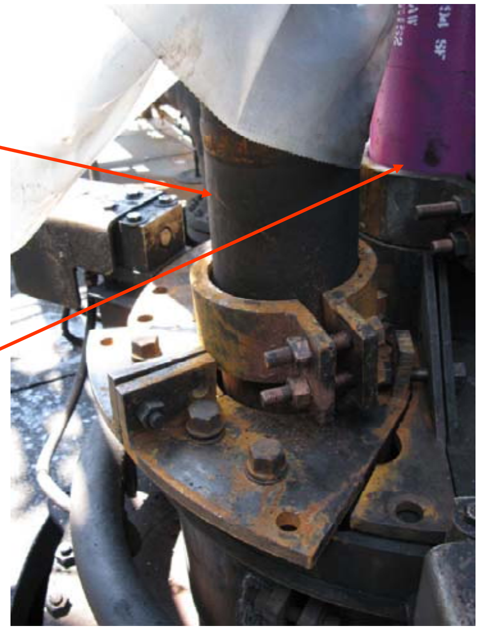
Freeing the Stem – Attempt 2:

Stuck Drill Stem, after detaching from rotary joint, was clamped to Side



Second drill stem provided to cut coke from bottom.

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Attempt 2 Successful:

View down the hole, after 2nd drill stem cut through the coke

The majority of coke had fallen through when the cone area was being enlarged.

The partially coked resid had stuck in that lower area. The second drill stem allowed the coke to be cut into the pit.

Delayed Coker Partial Derrick Collapse

Why Did the Derrick Fail?

Failure of a Derrick Structural Component is rare in ExxonMobil's Experience

Historically we have failed the sheave, sheave bolts, the cable, the winch, and the rotary joint attachment bolts

Stuck drill stems and coke falls do not typically result in derrick damage

=> none in XOM in over 30 years

=> few in industry over the last 30 years based on FS and R-P

Possible reasons that the event is infrequent:

- 99% of coke falls do not involve partially coked resid, which would act like glue on the drill stem and cutting bit
- Pneumatic-powered hoists have an inherent damping characteristic due to the compressibility of air, which reduces chance of high shock loading
- Pneumatic winches with poorly maintained brakes can be less likely to hold;
  => brakes should be maintained to allow repair, overhaul and maintenance of the lifting equipment

Delayed Coker Partial Derrick Collapse

Why Did the Derrick Fail?

Generic winch / drill stem components design load factors:

Today's winches can provide about 8 - 11k lbs of force (4 - 5k kg)

=> Translates into about 32 - 44k lbs (15 - 20k kg) of force via mechanical advantage gained by using a four-part reeve in the block and pulley

=> Slack cable trip occurs @ 4 - 6k lbs (1.8 - 2.7k kg) of tension (at winch)

=> High tension trip occurs @ 6 - 8k lbs (2.7 - 3.6k kg) of tension (at winch)

A review of the Joy winch design showed the winch force plus the brake force was 21k lbs (10k kg), so given the 4:1 pulley, a force of 84k lb (38k kg) would be needed to pull the winch backward

Braided steel cable can withstand about 53k lbs (24k kg) of force

Coke Drum derrick structures are designed to handle the static winch pull force plus a design safety factor (typically 1.3), or 57k lbs (26k kg)

The ultimate tensile strength of the W8 x 24 beam was calculated to be on the order of 55k lbs (25k kg) of static load

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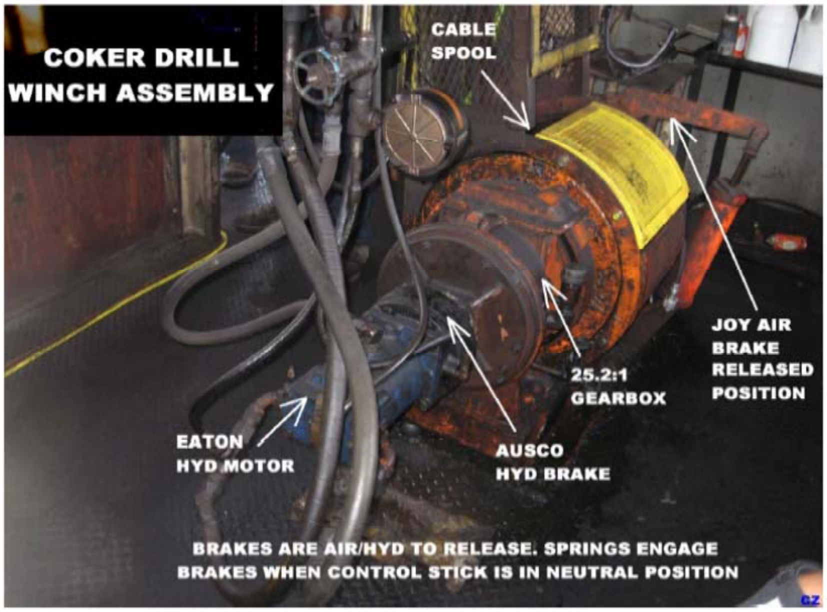
Why Did the Derrick Fail?

Not because of the winch.

The winch brakes worked (no disc/rotor burns). Sheaves all in proper position.



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Why Did the Derrick Fail?

Not because of the cutting tool

The new, sleek 13-inch (33 cm) diameter RuhrPumpen tools were in place

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Why Did the Derrick Fail – Shock Loading?

How much shock loading can be created from a falling stem?

1 ft (0.3 m) fall creates 12k – 16k lb load for cable from 100 – 250 ft in length
(5.5k – 7.3k kg) (30 – 76 m)

2 ft (0.3 m) fall creates 15k – 21k lb load for cable from 100 – 250 ft in length
(6.8k – 9.5k kg) (30 – 76 m)

=> the structure load will be 4 times these values, up to 84k lb (38k kg)

If a wire rope could handle 40k lbs (18.2k kg), it could withstand a fall of 8 – 21 ft (2.4 – 6.4 m) for a cable length from 100 – 250 ft (30 – 76m)

In the event of a falling stem full of water, the derrick structure shock load could be as high as 4 times that rope strength, which could be 160k – 250k lbs (73k – 114k kg)

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Did the Derrick Fail due to Shock Loading?

Dr Wolfgang Paul of R-P – "In 2005, a derrick failed when a drill stem was stuck in the coke bed. In that case, the coke cutter created a partially slack cutting cable (within the slack rope mechanical device winch stop limits) and then applied full winch load a number of times. This repeated dynamic load caused the derrick structure to fail. Because it is a new system in an old coker, they captured the cable tension readout in the DCS. Data trends revealed that the coke cutter performed that operation 23 times before the derrick failed. Derrick collapse was due to overload of old structure by high dynamic forces. "

RuhRPumpen provides a dampening function in their electronic controls to prevent the immediate application of full winch force on the cable, which reduces the dynamic force on the derrick and cable in stuck drill stem situations.

This site checked and found that they have electronic controllers between the joystick and the hoist motor…… the joystick sends a signal to a controller/transducer which in turn sends an output to hydraulic solenoids.

Coke cutters were interviewed and none stated that they applied full winch force repeatedly. Still, in the absence of data, it cannot be ruled out conclusively.

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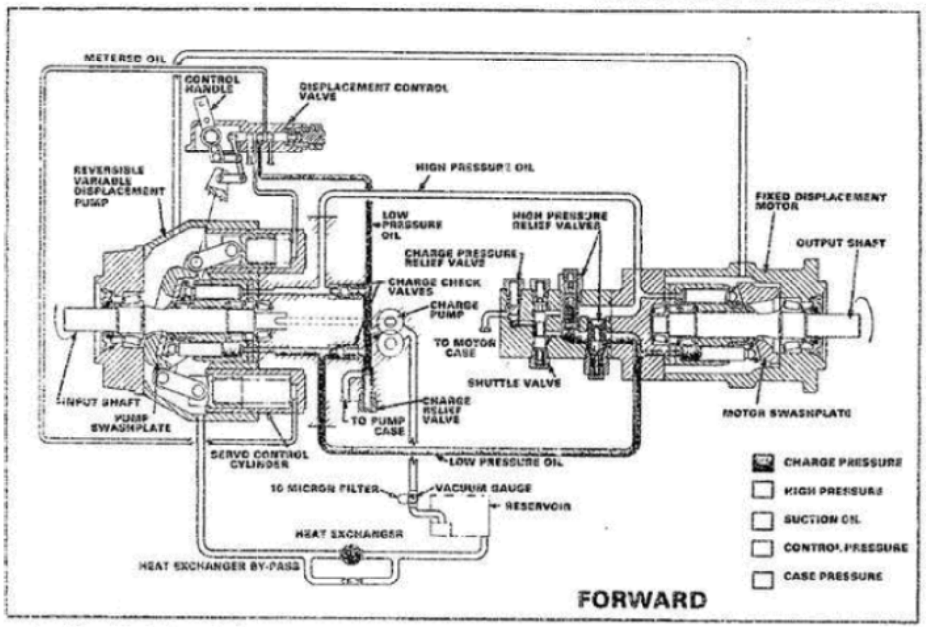
Why Did the Derrick Fail?

TYPICAL HEAVY DUTY VARIABLE PUMP—FIXED MOTOR TRANSMISSION SCHEMATIC



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Why Did the Derrick Fail? Two Possibilities

1 The drill stem was stuck in the coke bed (a mix of coke and partially coked resid), the coke cutter left the winch in neutral, which engages the brakes of the hydraulic winch, and there was a coke fall. The falling coke created an impact load on the stuck drill stem.

The weight of the falling coke exceeded the yield strength of the derrick structural cross members.

=> The coke bed had ~260 tons of coke plus any water suspended in or above the bed. If 50 tons of dry coke fell, that would generate 100k lbs of force, enough to yield the derrick structure.

=> The potential force generated by a coke fall is probably more, given that the amount of coke and water falling are large variables.

2 Repeated shock loading by the hydraulic winch

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Flowserve Observations from Flowserve & Doug Adams

Retrofits

FLS believes that a review of older towers, especially when doing retrofits, is a vital part of the process. These older towers were not designed with the same strength as today's towers and certainly deteriorate over time.

"…close attention always needs to be paid to either limiting the winch to the same performance of the original winch or verifying the structural integrity during hydraulic winch upgrades. I've long been concerned… [when hearing talk] about the merits of hydraulic winches being able to deliver extra pulling power on demand to get out of collapsed coke beds."

[In one instance]….a Flowserve pneumatic winch was replaced with another vendor's hydraulic winch, which simply ripped a pulley block out of the structure.

[In a second instance a site]…. went out on the open market without Flowserve input and bought a standard pneumatic winch which was not properly geared for the decoking application.

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Flowserve Observations (courtesy of Andrew Worley)

Slack Cable and Cable Over-tension

Flowserve started providing a tensiometer for slack cable and over-tension that stops the winch in the early 1980's when control systems first started becoming PLC based.

In the last 5 years, Flowserve has recommended and implemented moving the tensiometer to the deck to ease wire rope maintenance and ease operations by simplifying the operator integrations with the winch/tensiometer system.

Shock Loading of the Tower

Flowserve's standard control system supplies ramping functions for both the hydraulic and electric winch drive options to keep from shocking the winch and the tower.

Original pneumatic systems did not have this function, but due to the compressibility of air, the ramping was inherent in the system. The electronic ramp function is standard in all of the new Flowserve designed pneumatic systems

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RuhrPumpen Observations from Jay Jones

Current R-P Design approach for High Tension trip point at hoist

a. Trip device is load cell at top pulley plus overload protection via the PLC system (high pressure for hydraulic systems, high amps for elec systems)

b. Hydraulic Hoist limit set by pressure relief valve (2800-3200 psig), which equals 100% hoist capacity (44k lb) (without dynamic factor).
With a hand operated valve, very high dynamic loads can be realized without a ramp function integrated into the control system. Scenario - Operator lowers drill stem assembly until slack rope trip activated, then rapidly reverses direction - wire rope acts as a spring and load (dynamic) is greatly increased.

c. Electric Hoist - Motor Torque (electrical load) in the VFD. Normal operation set point is 70% max load (7.7k lbs [3,5k kg] @ hoist; 31k lbs [14k kg] @ crosshead) without dynamic factor. With Operator activation (push button), max load (11k lb [5k kg] @ hoist and 44k lb [20k kg] @ crosshead) due to reduced speed can be realized without tripping. Like the hydraulic system, a speed ramp function will greatly reduce the dynamic load.

d. Care is taken during revamps to keep max load within derrick limits.

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Causes & Follow-ups:

(1) Inadequate Management of Change

(A) On-Line Spalling Time Reduction within 14-Hr Cycle

Created a situation where there was less time for resid to become coke, increasing chance of additional partially-coked feed in the coke bed

Spall started late (6 hrs after switch), which should have required extending the spall termination until after the drum switch

(B) Furnace Air Preheater Controls Change

Control systems change on the ID Fan Guide Vanes as part of an Instrumentation Replacement Project was not well communicated

As a result, the console supervisor did not know that he had to override the 25% limit being enforced by the new system

So, he thought the ID vanes were at their normal 10% open position

This increased the time to cool the pass temperature before feed could be reintroduced, increasing amount of partially-coked resid in coke bed

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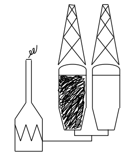

Causes & Follow-ups:

(2) Drill Stem Hoist System Design

Review of the system showed it to be adequate

Main question concerned which component should fail first – winch, cable, sheave, pulley, derrick, crosshead

Review indicated that it is not really practical to design a weak point into any component.

=> The proper approach is to avoid cutting coke beds with significant unreacted resid.

=> Procedures strengthened to strip coke beds with significant partially-coked resid with steam for extended period of time (12 – 24 hrs depending on amount)

=> R-P suggested using cable tension and elevation readouts to enhance cutting procedures for known low-temperature coke drums

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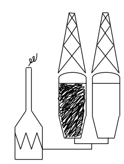

Causes & Follow-ups:

(3) Higher % of Maya Resid in Feed than Normal

This was a contributing factor since Maya resid has a higher foam front, which also contributed to the need to switch out of the coke drum earlier than desired

(4) Autoshift Cutting Bit Retrofit

Having an autoshift tool could have allowed the drill stem to be freed and have avoided the derrick collapse.