IMPROVEMENTS IN LIFE EXTENSION AND DESIGN PRACTICES OF COKE DRUMS

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In memory of Tom Farraro and his contribution to coke drum technology and his dedication to plant safety
Today’s Agenda

• What causes coke drums to crack?
• Measurement and monitoring of actual coke drum loading and operating conditions?
• Design considerations for fatigue resistant coke drums.
Coke Drums
Some Key Points of the Coking Cycle

Hot vapor fills drum, which grows larger.

Hot oil (900F) fills the drum and hardens as it cools, cracks and releases vapor.

Steam is used to remove volatile vapor.

Water enters from bottom to cool the coke bed, becomes steam and flows up the center or outside along the walls.

The coke drum contracts in diameter and height as it cools and “crushes” the coke.

Eventually water can form and fills the drum.
Why Coke Drums Crack - Review

- Most **not** designed for low cycle fatigue or the compressive strength of coke, unless requested
- Not designed using “Actual” measured thermal transients or stress ranges from daily operation
- Fabrication practices and QA/QC are more critical
- Now operating on shorter cycles (16-10 hr) and MUCH higher stresses for which they are not designed
  - Stresses on drum and surrounding piping and components are much greater at shorter cycles
- Running different feed stocks, i.e. Mayan, which produce harder coke
- Daily operating practices are inconsistent, which can cause significant damage
Coke Drum Failed During Quench After Repair

Coke Drum Failed During Fill
Drums are affected by:

1. Switch temperature (skirt)
2. Quench procedures (shell)
   - Steam and Water amounts and rates
   - From the top or bottom? Top is bad!
   - Anti-foam can act like a quench
   - Bug water
3. Feedstock changes affect coke hardness
4. Cycle time changes, shorter is worse!
5. Consistency of operation
6. Human factors
Cracked Skirt to Shell weld 4 Drums– 1369 Cycles or about 5 Years (SES Predicted 1228 Cycles)

- Design (by others) predicted 152 years
- SES Transient analysis performed prior to T/A
- Maximum stress intensity range during transient = 143,430 psi
- Using ASME code Section VIII Division 2 fatigue design Table 5-110.1, UTS < 80 ksi, a fatigue life of 1228 cycles was obtained.
Skirt is Pushed and then gets Pulled by Knuckle

DISPLACED SHAPE AT THE END OF FILL

DISPLACED SHAPE 1 HOUR INTO QUENCH

(MAXIMUM STRESS DURING QUENCH OCCURS HERE)
Critical location for maximum stress range during Fill and Quench

AXIAL STRESS DURING FILL AT MAXIMUM STRESS TIME
What is Health Monitoring?

- Instrumentation much like your process instrumentation but using strain gages and thermocouples to measure and control “actual” drum damage
- Measures “actual” drum response (stress range) to daily cycling, temperatures and strains
- Calculates fatigue damage per cycle
- Compare response from one operating scenario versus another so adjustments can be made to reduce high stress events, i.e. optimization
- Used like a speedometer to measure how fast drum life is being used up by cycling
High Temperature Strain Gage Locations at Bulge
A Cycle For In-Line Skirt Response

Location 1

Temperature

Axial Stress

Hoop Stress
Fill and Quench Transients Overlaid with Process Information
Histogram of Heating and Cooling Rates

Max Rates for Quench 30 cycles 2003

Max Rates for Quench 40 cycles 2004

STRESS ENGINEERING SERVICES INC. committed to technical excellence
Histogram of Skirt Switch Temperatures
Histogram of Stress Ranges and Fatigue Damage

These Few Cycles Create A Lot Of Fatigue Damage
Drum Quenching Modifications Example

Comparison of Quench Water Flow Profiles

Quench Water Flow, gpm

Time, minutes

- Current
- 1st Change
- Original

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Laser scan with HTSG locations on drum
Bulge Map - Prioritizing Locations

THROUGH WALL CRACK August 2005!

(B) Maximum BIF (A)

Crack away from weld (BIF=1.82)
Hydrotest of new coke drums with AE inspection

(Code Max. Press. Modified to reach past 1 ½ Design to find smallest defect possible)
Permanent AE Monitoring of 2 Coke Drums In-service

Data acquisition when TC’s A and B (both) are above 300 F
4 AET transducers on each (W1, W3, W4) welds at each drum
Total of 24 AE transducers. Remotely calibrated AET transducers
Two TC controlling data acquisition (TC-A, TC-B)
Six TC’s monitoring skin temperatures for thermal gradients
State-of-the-art Digital AMSY4 Vallen System, remotely operated
Why are there more problems now?

- Drum cycles are shorter (24 down to 12 hour cycles)
  - Lower switch in temperature
  - Heat and cool faster high thermal transients
  - Production value is greater = expensive outage
- Fabrication practices and defects
- Cladding can initiate cracks in base metal
- 1 1/4 Cr alloys become brittle with age
- Feedstock changes more often, quality and hardness issues
- Graduated wall thickness drums crack within 4-7 years
- Thinner drums bulge more and crack more
Discussion of Factors Used for Design and Comparison of New Coke Drums

1. Fatigue Cycle Life
   1. Current life is typically 1500 - 2500 cycles, 5 years.
   2. New design life target 7000 – 10,000 cycles

2. Material – 1 ¼ Chrome versus 2 ¼ Chrome?

3. Weldability – Can it be fabricated or repaired?

4. Thickness required to “crush” coke?

5. Fracture toughness and resistance to embrittlement?
Summary How to Improve Your Drum Design

• Request a Fatigue Resistant Design
  ▪ Ask for it

• Use Actual Transient Loads for Design Loading Calculations

• High Yield Strength Plate Material (2 ¼ Chrome is stronger and less brittle as it ages)
  ▪ Slows down bulge formation

• High Quality Welding in Shell and Skirt
  ▪ No Defects
  ▪ No Weld Caps

• Uniform Plate Thickness Top to Bottom
  ▪ No Transitions
  ▪ No Stress Concentrations

• Fatigue Resistant Skirt Design
**SES Coke Drum Experience**

- SES has installed 25+ “HMS” on > 50 drums since 1999 and monitored more than 5000 cycles
- SES has carried out Acoustic Emission tests, new and in-service, for > 60 coke drums
- Fatigue analysis of several DeltaValve installations
- Assessment of structures and piping systems
- Monitoring and analysis of blow-down lines
- Bulge Assessment using “BIF” to prioritize which bulges will crack first
- SES is presently designing more than 30 coke drums using our fatigue resistant design approach
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