SEATTLE - Houston-based Equilon has agreed to pay $45 million to settle a lawsuit filed over the deaths of six workers in a 1998 Anacortes refinery explosion.
Improvements since the 1998 Equilon Puget Sound Refinery Coke Drum Incident
DCU Safety & Reliability
Ongoing Video by local media during the event.
1998 Equilon DCU Fire Fight....

Figure 2. Fire control efforts at Equilon refinery.

Matt Wallis, Skagit Valley Herald
Shell Delayed Coking in the US

Shell Puget Sound Refinery - DCU

26.9 MBPD Heater Feed, 2 Drums - 26', 15 Hr. Cycles
Typical Gas Plant and Blowdown vapor recovery
Equilon Puget Sound Refinery Incident

- Incident Description
- Contributing Factors
- Investigation: Summary of what happened
- Findings
- Recommendations
- Learning’s
Coking – Process Overview
Simplified Process Flow Diagram of a Delayed Coker
Description of Equilon Incident
Unit Overview

• This Two Drum DCU is situated along the shores of Puget Sound in Anacortes, Washington.

• In 1998 this refinery was owned & Operated by Equilon and was a legacy Texaco Refinery. Presently it is owned and Operated by Shell Oil Products.

• Unit Safe Guarded Capacity is 26,880 BPD DCU Heater Feed

• Unit was Operating on 15 Hour Cycles on 11-25-1998

• Normal DCU configuration.

• Crude Processing Department staffing for the DCU

• Operators rotate between two units – Crude and Coker

• Contractor WPSI did Coke Drum Un-heading, Cutting, Coke Handling, Drum Re-heading, Maint. – all done by the CHD Dept
# 15 Hour Drum Cycle - November 1998

<table>
<thead>
<tr>
<th>Time &amp; Date</th>
<th>Cycle Step</th>
<th>Drum</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/24/98 8:00 PM</td>
<td>Steam Test - earlier if drum is ready</td>
<td></td>
</tr>
<tr>
<td>11/24/98 8:30 PM</td>
<td>Warm Up - earlier if drum is ready</td>
<td></td>
</tr>
<tr>
<td>11/24/98 10:00 PM</td>
<td>Warm Up Transfer Line</td>
<td></td>
</tr>
<tr>
<td>11/24/98 11:00 PM</td>
<td><strong>Switch Drums</strong></td>
<td>B to A</td>
</tr>
<tr>
<td>11/24/98 11:01 PM</td>
<td>Steam to C1 @3.5 Lines</td>
<td></td>
</tr>
<tr>
<td>11/24/98 11:30 PM</td>
<td>Steam to C-104 @9.5 Lines</td>
<td></td>
</tr>
<tr>
<td>11/25/98 12:30 AM</td>
<td>Start Cooling Water</td>
<td></td>
</tr>
<tr>
<td>11/25/98 5:00 AM</td>
<td>Shutoff Blowdown Blocking and PRV Steams</td>
<td></td>
</tr>
<tr>
<td>11/25/98 6:00 AM</td>
<td>Unhead</td>
<td></td>
</tr>
<tr>
<td>11/25/98 8:00 AM</td>
<td>Steam E106's and G-16 Strainers</td>
<td></td>
</tr>
<tr>
<td>11/25/98 11:00 AM</td>
<td>Steam Test - earlier if drum is ready</td>
<td></td>
</tr>
<tr>
<td>11/25/98 11:30 AM</td>
<td>Warm Up - earlier if drum is ready</td>
<td></td>
</tr>
<tr>
<td>11/25/98 1:00 PM</td>
<td>Warm Up Transfer Line</td>
<td></td>
</tr>
</tbody>
</table>

*Cycle Interrupted by Major Utility Failure ~1 Hr after Switch*
Description of Equilon DCU Incident

Tuesday, November 24th 1998

- Drum A - Approx. 1100 Bbls of Charge in 1 Hour
- Power Outage - 12:01am
- Loss of steam following power outage
- Power Restored - 2:00am
- Unit on Circulation - 4:00am, Drum A Isolated
- Steam Restored - 12:30pm
- Attempted to Steam Into Transfer Line to Drum A
  - 16 hours after loss of flow –
- No Work Overnight – Drum allowed to cool on its own
Description of Equilon DCU Incident

Wednesday, November 25th 1998

• Drum Temperature Data Reviewed in Morning
• Discussions Held - approx 10:30am
• Two Additional Steaming Attempts are Made
• Permit is Issued to Unhead with Fresh Air !!
• Top Head Removed - 12:50pm
• Deheading Cart Positioned
• Bolts Removed and Head Lowered - 1:23pm
• Fire with Six Worker Fatalities
Summary of Equilon DCU Incident

Contributing Factors – Process Only

- **Total Loss of Power Steam with Transfer Line Plugging.**
  
  ➢ CoGen down due to loss of main power line to west side of refinery,

- **Bottom Flange, Cone, Feed Piping Cool To Touch**
  
  ➢ Insulating Crust – “R” factor same as mineral wool & TI’s do not measure bulk thermal mass

- **1996 Water Incident on a Partial Drum**
  
  ➢ Drum would not Drain & Difficulty in Removing Head

- **Cooled “Gooey Tar Balls” Removed in the Past**
  
  ➢ Much less Feed and Drums Steamed & Cooled
Morning of Incident –
All temperatures appeared
to be decreasing, indicating”
that the drum was cooling.

Investigation:
Summary –
What Happened?

Cooling from the
Outside - Inwards

90 F, 245 F @ Dehead due to steaming attempt
Investigation: Summary - What Happened?

➢ ~4”
➢ 1,100 BBLS - center at ~650 F
➢ VISC = similar to water @ 650 F
➢ Head = 20’ or 8.5 psig = 6 sec gravity flow of total amount.
➢ Min ~300 gals of H2O + Liquid HC was pooled on top of Crust
➢ Lowered Head – Tar, then Hot Oils begin Flowing out drum and auto-ignite.
➢ Crust on top of mass fails & liquid on crust falls to hot center.
➢ Rapid Expansion of Liquid occurs with ensuing fire ball and very forceful expulsion of partially formed coke, residuum, & gas oils - out 75’ in ~2 secs, in all directions.

F = 114.6 Tons

~ 100’ Fire ball emitted from bottom of Coke Drum.
Investigation: Summary
- What happened - What went wrong -

➢ ~4” thick Crust

➢ 1,100 BBLS - Center of Mass at ~650 F

➢ Viscosity = similar to Water, since Mass was at 650 F

➢ Head = 20 Ft or 8.5 psig = 6 Sec Gravity Flow of Total Amount.

➢ Min ~300 gals of H2O + Liquid HC was pooled on top of Crust

➢ Lowered Head– Tar, then Hot Oils begin Flowing out Drum and auto-ignited.

➢ Crust on top of mass fails & liquid on crust falls to hot center.

➢ Rapid Expansion of Liquid occurs with ensuing fire ball and very forceful expulsion of partially formed coke, residuum, & gas oils - out 75 to 100’ in ~2 Seconds, in all directions.
Investigation Findings

➢ There were no pressure vessel or piping integrity failures found.

➢ Procedures were in place for normal, routine operations of Coke Drums.

➢ There was a loss of steam and subsequent plugging of the coke drum charge line. No ability to steam strip and cool the drum normally.

➢ The effective insulating layer of cooled residuum and coke on the wall and bottom head did not provide operators with indications of the hot liquid center.

➢ The temperature indicators on the coke drums would not indicate temperature in the central mass of the drum. They do not measure bulk temperature.

➢ In cases where a partially charged drum has occurred, along with the loss of steam, care must be taken relative to water addition to the coke drum. Rapid flashing of steam can be extremely hazardous.

➢ The fire resulted from auto-ignition of the hot drum contents emptying from the bottom head during Deheading.

➢ The team's opinion was that egress was probably not an issue in this particular incident because of the rapid nature of the release.
Investigation Findings (cont)

➢ In the case of significant DCU events, review by both Operations and Technical Personnel is necessary. If normal procedures do not apply, specific written plans and procedures are required. Call for help! Involve Everyone.

➢ Conduct a study of options such as alternate steam sources, other purge media, to keep the transfer lines clear in the event of power or steam outages!

• We reviewed and selected the most reliable utility in the Plant – Natural Gas. Works great and has been used many times at our locations since 1999.

➢ Revise drum Deheading and cart Tugger controls to a more remote location.

➢ Develop tools such as a predictive model for coke drum internal temperature that operators can use in the case of changes from normal drum cycles.

➢ Continue to involve WPSI (Coke Contractor) personnel in significant events involving drum Deheading. Communications: MOC's

➢ Review all DCU Operating procedures and compete a pre-start up safety review prior to re-starting the unit. Review the existing Hazop study and address any open items.
Summary of Equilon Incident
- Learning and Training -

➢ Fundamental – Heat Transfer
➢ Fundamental – Force, \( F = \text{psig} \times \text{Area (Sq In)} \)
➢ Fundamental – “Roll Over” Phenomena rapid vaporization 1,020 Gal = 75 PSIG; Drum damage
➢ Coking Fundamental Review – Coke Formation
➢ Procedure Development – Technical Reviews proper Tech Expertise, Warnings/Cautions
➢ Changing Existing Procedures
➢ Incident Database to Support the above
Learnings

Fundamentals:

➢ **Heat Transfer**: Steaming and cooling the drum is the practice and teaching in the Industry, however, the fundamental knowledge of the heat transfer during Drum cooling may not be well understood by all operators

- Heat loss from a hot Coke Drum allowed to just sit and cool by thermal and surface conductivity would take months due to the insulating properties of residuum and coke. (Per WA State L&I – 236 Days)

- If it is a short drum with a concern about draining, then it can be pumped out the top. Drums must be cooled!

- Past Unit Examples: Normal Coke Drum hot spots; Heater Tube Coking; Residuum Shell & Tube Coolers and Cooling Box buttering.

- Past Plant Examples: FCCU Spent Cat Hopper, SRU Sulfur Beds, HTU & CRU Rx’s – all very hot, take long to cool - same heat transfer principles

➢ Coker Fundamental Review of Coke Bed formation and Quench Water flow in to the Drum – review “channeling”

➢ "Roll-Over" Phenomenon During Tar Drum Cooling is a big concern review mitigations when quenching from the Top.
55 Gallon Drum Temperatures After 24 Hours

- After 24 Hrs - Insulated Drum has 6" Boundary Layer
- Insulated Drum With 11 Inches To Drum Wall & 13 Inches To Outside Insulation
- Bare Drum With 11 Inches To Drum Wall
- After 24 Hrs - Bare Drum is Solidified
- 41.5 HRS
Next Step: Coker Safety Technology

Equilon 1999 DCU Safety & Reliability Study

*Study included 8 units* - PSR, MR, LAR, BKR, EDR, DPR, PAR, NR. BAR in 2006

The Study Team = 3 Technologists/Managers from Shell WTC, 4 Ops from Operating Units including Brent & Tom!

- *Typical Study Recommendations for implementation*

  - Facilities (23)
  - Base Level Practices (50)
  - Written Procedures for Normal Operation (20)
  - Written Procedures for Emergency Situations (20)
  - Successful Practices (40)
  - Site Specific Recommendations (50-100)

*Note- numbers are average recommendations made for each plant.*
Coker DCU Safety Study Methodology

LOPA (Layers of Protection Analysis)

Developed by Shell’s Arthur Woltman in 1993 with the AIChE Center for Chemical Process Safety
Coker DCU Safety Study Methodology
Model Bowtie done for units Pre-implementation after 2006
PSR DCU 2011 Safety Project Training

Delayed Coking Model Bowtie

- Original Model Bowtie was developed in 2009 at WTC
- Several Reviews done in US and AMS.
- Used for several large projects – BAR, PSR

- Did a verification at each DCU Location
  - Martinez review was done May 2011
  - Norco review was done in August 2011
  - Deer Park started needs to be completed as of 2012
  - Puget review of Project MBT completed in 2012
  - Buenos Aires MBT review to be completed in 2013
  - Port Arthur DCU-1 completed in 2012
## Delayed Coking TDN Safety Score Card

### Delayed Coker Safety Facilities

#### Refinery Locations

<table>
<thead>
<tr>
<th>Coker Safety - Layer of Protection Item</th>
<th>Deer Park</th>
<th>Port Arthur</th>
<th>Norco</th>
<th>Los Angeles</th>
<th>Puget Sound</th>
<th>Martinez</th>
<th>Buenos Aires</th>
</tr>
</thead>
<tbody>
<tr>
<td>Furnace PRV's</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Alternate Emergency Egress Means</td>
<td>ramps</td>
<td>ramps</td>
<td>Chutes and ramps</td>
<td>Phase II - 2006</td>
<td>ramps</td>
<td>Chutes</td>
<td>Lateral staircase (depot from BP)</td>
</tr>
<tr>
<td>Fire Suppression</td>
<td>yes</td>
<td>yes</td>
<td>Yes</td>
<td>Phase IV - 2009 TIA Project</td>
<td>yes</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Deluge System</td>
<td>yes</td>
<td>yes</td>
<td>Yes</td>
<td>Phase IV - 2009 TIA Project</td>
<td>yes</td>
<td>yes</td>
<td>No</td>
</tr>
<tr>
<td>Remote Bottom Unheading System</td>
<td>yes</td>
<td>yes</td>
<td>Planned Delta</td>
<td>Yes, Delta</td>
<td>yes</td>
<td>yes</td>
<td>No</td>
</tr>
<tr>
<td>Remote Feed Line Opening (Grayloc Flanges or equivalent)</td>
<td>yes</td>
<td>yes</td>
<td>Planned Delta 2005</td>
<td>no need for Grayloc</td>
<td>yes</td>
<td>yes</td>
<td>No</td>
</tr>
<tr>
<td>Automated Top Head Handler</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>Phase II - Scheduled During Decade</td>
<td>yes</td>
<td>yes</td>
<td>Manual, controlling device for drill bit (and stem)</td>
</tr>
<tr>
<td>Auto-centering device for top cover orland drill bit and drill stem</td>
<td>yes</td>
<td>no - PRV's will be in place in 2007</td>
<td>yes</td>
<td>Phase II - Scheduled During Decade</td>
<td>yes</td>
<td>yes</td>
<td>Partial</td>
</tr>
<tr>
<td>Interlocks</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>Phase II - Scheduled During Decade</td>
<td>no</td>
<td>yes</td>
<td>Partial</td>
</tr>
<tr>
<td>Feed line purge in case of steam failure</td>
<td>Risk Assessment Complete Project for 2007</td>
<td>Yes (Natural Gas)</td>
<td>Yes (Hydrogen)</td>
<td>Phase IV - 2009 TIA Project</td>
<td>yes (Natural gas)</td>
<td>Yes (Secure steam supply)</td>
<td>No (only MPS as emergency feed at turnaround)</td>
</tr>
<tr>
<td>All double blocked Isolation Valves</td>
<td>yes</td>
<td>Upgrade - 2007 TIA Project</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Blowdown Flow Meters</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Blowdown Vapor Recovery</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>No</td>
</tr>
<tr>
<td>Coke Cutting Shelters &amp; Instrumentation</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>Phase II - Scheduled During Decade</td>
<td>yes</td>
<td>yes</td>
<td>configured totally enclosed</td>
</tr>
<tr>
<td>Combination tools</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>No</td>
</tr>
<tr>
<td>High pressure cutting hose chains</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>No</td>
</tr>
<tr>
<td>Drilling Stem Free-fall arrestors</td>
<td>yes</td>
<td>yes</td>
<td>no</td>
<td>Phase IV - 2009 TIA Project</td>
<td>yes</td>
<td>yes</td>
<td>No</td>
</tr>
<tr>
<td>Compressor Anti-surge system</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>No</td>
</tr>
<tr>
<td>Re-route vent discharges</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>No</td>
</tr>
<tr>
<td>Add Coke Drum Vacuum Indication or dual range PI warning</td>
<td>Yes - Completed in 2005</td>
<td>yes</td>
<td>No, not needed since we pressure out</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Two sets of top and bottom warning</td>
</tr>
<tr>
<td>Programmed, Independent Quench System</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>Phase IV - 2009 TIA Project</td>
<td>yes</td>
<td>yes</td>
<td>No</td>
</tr>
<tr>
<td>Isolate Power Distribution and Supply for MOV's (or equivalent means to prevent spontaneous movement of MOV's)</td>
<td>yes</td>
<td>yes</td>
<td>MOV Buttons and:pointer Upgrade</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes, manual</td>
</tr>
</tbody>
</table>

### 23 Layers of Protection

- **Vision** – No Person on the Structure!
DCU Incidents –

1.) Site and company Incidents – Analyze, RCA, 5-Why, etc. Document and Train.

2.) Keeping Up with the Industry Incidents – Sharing as allowable. Coking.com, CSB, OSHA, CCCP

Documenting and Benchmarking is Essential –
Observation:

Roughly 2 significant Coker incidents reported per year

— List of incidents – Next
Delayed Coking Incidents

- Improper Drum Isolation
- Coke Drum Cracking
- PMI Failure
- Shot Coke
- Tarry Drums
- Drilling Incidents
Incident Photos

Hovens, St Croix - 2004
Shell BKR - 2005
Exxon Baton Rouge - 1993
LCR Pasadena - 1999
Tosco Carson - 2001
Fundamental Process Challenges for Delayed Coking

- Coker Heater Outlet Lines
- Coke Drum Vapor Lines
- Coker Fractionator Coking

- 24” Coke Drum Vapor Line
- Foamovers – Major Plugging
- HCGO Draw Manway
- Wash Oil Spray Header
2007 Safety Study Revisit at PSR – Post 2005 Upgrade Project
Head lowered remotely - Since 2011 there are Slide Valves
Known Major DCU Incidents in past 19 Years (as of 2012)

- Exxon Baton Rouge – 1993 – Three Fatalities - Six inch Heater Inlet elbow, Carbon Steel in 5 Chrome line. Loss of life and unit destroyed > $150 MM. PMI failure
- Citgo Corpus Cristi – 1994 - One Fatality - when In-Service Coke Drum was accidentally Deheaded. Loss of life and major unit damage.
- US Refinery - 1997 – One Fatality - when In-Service Coke Drum was accidentally deheaded. Loss of life and major equipment damage.
- Conoco Lake Charles - 1999 – One Fatality - resulted from welding on top of Coke Drum when vapor released caused flash fire. Improper Drum Isolation, valve leakage. Loss of life and equipment damage.
- Amoco Whiting - 2000 – One Fatality - caused by Drill stem retraction from the Coke Drum during cutting- interlocks bypassed. Loss of Life and Major damage to unit.
Known Major DCU Incidents in past 19 Years (as of 2012) (cont.)

➢ VEBA (BP) Gelsenkirchen, Germany - 2001 - **One Fatality** - when Operator was fatally scalded following the removal of the Top Head. Coke Drum eruption of scalding Hot Water and Coke. Close proximity of employees to Coke Drum. Loss of Life.

➢ Chevron Pascougoula – 2002 - **One Fatality** - resulted from a Contractor being severely scalded with hot water and coke while working near the coke pit during the Coke Drum Cut. Loss of Life.


Turnaround Incidents


➢ Chevron Pascougoula – 2003 **Two Fatalities** – during DCU Turnaround Construction, Coke Drum change out, from a Contractor fall from extreme height and a dropped Crane load. Loss of Life, equipment damage.

Continued Running Incidents

➢ Repsol Argentina – 2007 - **Two Fatalities** – during Bottom Deheading.

➢ Mexico City Pemex – 2008 - **One Fatality** – during Deheading.

➢ ExxonMobil Torrance – 2009 **One Fatality** – during Bottom Deheading. Operator Supervisor hit with Hot water when Bottom Head was dropped. 80% burns.
Known Major DCU Incidents in past 19 Years (as of 2012) (cont.)

- Resol La Coruna Spain – 2010 – **One Fatality** - Flash Fire, two seriously burned with one fatality – Drill Stem welding above Open Coke Drum which still had partial Coke Bed. Gas evolved from Coke Bed - investigation revealed all valves were holding.

- Holly Tulsa – 2010 - **One Very Serious Injury** - Hot water out of bottom head hit Coke crew with one sustaining burns over 70%.

- 25 Total Lives Lost
Keeping up with Technology Changes - Training Personnel at Sites – Staff, Engineering, Process and Operations.
Impacts of the Incident and Safety Study

Huge impact on the Industry - led to the development of the Slide Valve Deheading system

Slide Valve Deheading Systems

- Chevron and Delta Valve installed first one on the bottom of a coke drum in 2001 at Chevron Salt Lake

1\textsuperscript{st} Installation of Delta Valves at Shell Los Angeles in 2004 – 4 drums - Bottom
2\textsuperscript{nd} at Motiva Norco – 2006 – 2 Drums, Bottom installed in 2006
3\textsuperscript{rd} at Shell Deer Park – 2007 all 6 Drums – Bottom; Top installed in 2014
4\textsuperscript{th} at Shell Martinez – 2009 – 2 Drums – Bottom, then Top in 2014
5\textsuperscript{th} at Buenos Aries – 2010 – 2 Drums – Top and Bottom
6\textsuperscript{th} at Shell Puget Sound – 2011 – 2 Drums – Top and Bottom
7\textsuperscript{th} at Motiva Port Arthur – 2012 – 6 Drums – Top and Bottom – Zimmerman & Jansen

Remote Coke Cutting -
1\textsuperscript{st} Shell Buenos Aries 2010
2\textsuperscript{nd} Shell Puget Sound 2011
3\textsuperscript{rd} Motiva Port Arthur 2012
What about Process/Ops Changes to mitigate?

Procedures have been Developed in the Industry and within Shell to help mitigate Tarry Drums -

- **Water Quench using BTU Balance method** – Issues can be Rollover from Water Flashing. Tar in the Chute and Pit and even Crusher – one location asphalted their Pit losing ½ the volume! Also – results in high VCM Coke so must be sold as Fuel or if very high must be disposed of.

- **Superheated Baking or “Cooking” of the Bed** - requires the use of the Heater so unit is taken out of Circulation – 900 F steam injected into the Coke Drum until top temp lines out. PAR did this in late 2012 and has done so since – produces on-test coke. Also used procedure for Whole Heater Spalling. Possible Option - run DCU Superheated steam to Steam/Water manifold if available.

- **Cutter Dilution Method** - Put LCGO in the Top, antifoam carrier, and then mix with Steam. Drain to Coke Drum Warm Up Drum pump to Blowdown and recycle or to slop

- **Decision Trees** – decision what to do with a Tarry Drum and if you should Switch Back in or Proceed to Baking or other methods.

- **Communications** – Technical Operations Network with routine Telecoms and Annual Meetings.

- **Training** – Have routine DCU Training for all operators an Process
Port Arthur – DCU2
2011 - 6
Z&J - Bottom
Installed Safety Facilities – Coke Drum Auto Deheading

“What we are doing to make it safe!”

Hahn & Clay with Grayloc

Delta Valves
Installed Safety Facilities – Coke Drum Remote Deheading

“What we are doing to make it safe!”

Remote Deheading at Grade

- Future -
  Top Deheading & Cutting from Remote Shelters
Installed Safety Facilities – Coke Drum Egress

“What we are doing to make it safe!”

Baker Life Chute

Stairway Fire Shields

Egress Towers and Ramps

Chute Entrance

Egress Deluge
Implementation - Auto Bottom Deheading

Hydraulic Grate and Chute

Locations with the Hahn & Clay Swing Away System
Implementation - Auto Bottom Deheading

Two Locations had Hahn & Clay-Foster Wheeler Systems
These have been replaced with Delta Valves Bottom and Top
Implementation - Auto Bottom Deheading cont.

Our 1st Location to install Bottom Slide Valves in 2004 Others Followed
Implementation – Remote Feed Line

Most Locations have Grayloc Flanges

Why you need it!
Implementation - Remote Deheading

Remote On-Structure Location

Remote Off-Structure Locations

Structure Cameras – 2 Per Drum
Implementation - Remote Deheading cont.

Remote Deheading Controls

Every Location has Remote Bottom Deheading

The Overall Structure must be Visible from Remote Shelter
Implementation - Emergency Egress

- Baker Life-Chute™ with steel cable
- Egress “ramps” to self standing Stairway Towers or Ladder Cages
- Fire Shielded Stairways to Grade
- Egress Water Deluge to assist personnel at egress pathways
- Egress “runways” over crane rails

Fire Walls
Implementation - Fire Protection & Deluge

- Extra Reciprocating Monitors
- Egress Lever & Heat Sensors
- Bottom Head Deluge
- Entire Structure
- Deluge - Testing
- Testing
Shelter must have Safety Equipment including Several SCBA’s or 5 min Escape Packs

Monitoring of Pit from Within

Camera Monitoring Pit

Looking at Fresh Air Supply to Shelter & Remote Top Deheading and Cutting

Moving Away from This – No Shelter!
Implementation – Coke Drilling Safety –
Drill Stem Interlocks & Free Fall Arrestors

Moving Away from Structure Incidents!
Free Fall Arrestors and Proper Inspection & Maintenance
Shell DCU Safety Project Training

Port Arthur – DCU-2
2011 - 6
Z&J - Bottom
Port Arthur – DCU-2
Z&J - Top
Implementation - Remote Top Deheading & Cutting

- The Vision -
  - Out of Harms way during Dehead
  - Out of Harms way during Cutting
  - No Blowout & Boil Over Injuries - No Exposure

Project: Complete Remote Top Deheading & Cutting

- Camera’s on Top Deck
  - Run Controls to Grade to Remote Bottom Deheading Shelter - BRM
- Completed in 2011
Coker Safety Conclusions

• Coker Safety First!

• Safety is a continuous process – ‘Stay Up with the Evolving Technology!’

• Keep Pushing and Following Up
Coker Safety Technology

1. Data Collection and Benchmarking

2. On Site Visit:
   - Interviews, Incident Discussions, and Field Observations, with Immediate Feedback on Areas of Concern and after action evaluation
   - Evaluation of Safety in Coker areas
   - Risk Assessment for each event/facility
   - Identification of Issues
   - Recommendations

3. Follow up on implementation
PSR has completed 22. The last item, Coke Cutting Instrumentation, will be completed during 2011 DCU Safety Project.

### Delayed Coker Safety Facilities

#### Refinery Locations

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<tr>
<td>1 Furnace PRV’s</td>
<td>No, Risk Assessment completed.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Not required per design</td>
</tr>
<tr>
<td>2 Alternate Emergency Egress Means</td>
<td>Ramps</td>
<td>Ramps</td>
<td>Baker Life Chutes and Ramp</td>
<td>Ramps, Deluge Egress</td>
<td>Baker Life Chutes</td>
<td>Yes - RA Done</td>
<td>Ramps</td>
</tr>
<tr>
<td>3 Fire Suppression</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes Structure Fire Water System</td>
<td></td>
</tr>
<tr>
<td>4 Alternate Top Quench (Top Deluge, unheading &amp; Cooling)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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</table>

23 Safety Facilities from the original 1999 DCU Safety & Reliability Study. Tracked by the DCU TechNet TDN and TIN, as well as the HSSE Americas and Project Management at Sites and in Houston.
### Delayed Coking Best Practices - Includes Updated Facilities

PSR has completed 22 out of 27 - 5 more under review or done as small projects

#### Delayed Coking Best Practices – 17 are additional Facilities

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<tr>
<td>1. Running lights at all decks (2nd, Vapor and top) to indicate the coke drums is in service.</td>
<td>NO</td>
<td>Indicating lights on switch and top deck.</td>
<td>2nd floor only</td>
<td>Yes, since mid 1990's</td>
<td>No</td>
<td>NO</td>
<td>Remote Operated Control Panels with Lights</td>
</tr>
<tr>
<td>2. Blowdown system sour water flow meters and totalizers.</td>
<td>Yes</td>
<td>Yes</td>
<td>total flow for SVI, but not strictly for blowdown. However it is calculatable. OSE provided procedure to</td>
<td>Project using Sonic Meters (Flexim)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3. Tack-welding of coke cutting nozzles. Flowserve Tools only.</td>
<td>Yes - Getting Delta Valve Auto Switch</td>
<td>Yes</td>
<td>Yes</td>
<td>Not Required on RP tools -Yes on Flowserve tools.</td>
<td>Yes, but we have had some break off.</td>
<td>Not Required on RP tools</td>
<td>Reviewing requirement for new Flowserve Tools</td>
</tr>
<tr>
<td>4. Monitor and plot delta P between drum and fractionator flash zone.</td>
<td>Yes, quarterly report and Radical</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes - A DCU KPI</td>
<td>Yes</td>
<td>Yes</td>
<td>Proposed - a part of Proactive Process Monitoring</td>
</tr>
<tr>
<td>5. Antifoam certificate</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

27 Delayed Coking Best Practices developed from 2004 - 2011. Developed and tracked by the DCU TechNet, TDN and TIN, as well as Project Management at Sites and in Houston
Photograph of dust plume from a Hot Coke Drum within refinery limits. Study done; facilities installed and these no longer occur.
Shell Delayed Coking Safety Project Meeting

Prior design practice

Slide Valve + Single Point Side Feed
PSR DCU 2011 Safety Project Training

Safety Project Focus

**Bottom Slide Valves** – LAR, NR, DPR, MR, BAR, PSR, PAR CEP DCU2  
PAR DCU-1 remaining

**Top Slide Valves** – BAR, PSR, PAR CEP DCU2. DPR and NR both have Projects >>>> DCU Model Bowties DCU-1 and MR remaining

**Dual Feed Inlet** – MR, Buenos Aries, PSR, PAR CEP DCU-2  Dual Feed and Retractable Feed Inlet under review by others.

**Interlocks** – new or Upgrades, PSR, BAR, PAR-DCU1, others reviewing Basis Model Bow Tie.

**Remote Coke Cutting** – BAR, PSR, PAR CEP DCU-2

**DCU IPF** – New or Upgrades PAR, PSR, NR, BAR

**Safety Facilities and Best Practice Facilities** – all locations  
Example – Coke Drum Levels: NBS plus Continuous Gamma at Top  
Other - Coflexip Decoking Hose – PAR, MR
Delta Valve Retractable Center Feed Device
Implementation – Other

Auto-Shift Combo Tool
Motiva Port Arthur DCU2

- Top and Bottom Z&J Slide Valves
- Remote Deheading at Grade
- Remote Coke Cutting at Grade
- Coke Drum Valve actuation from points of Egress (semi-remote)
- MOV/AOV of all valves including Blocking Steam and Drains
- Complete Interlock
- Egress Towers

95 MBPD, 6 Drums - 30', 18 Hr Cycles
Video Camera Views

- September 2012

4-Square View

Chutes

Top Head View

IR / Thermal Camera – Pit and Maze

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Key learnings & successful practices at PSR

Video is essential 'kit' for a coke handler. PSR requires a system which is reliable and will provide at least four views simultaneously. (Open head, winch drum, chute, and crane location.)

The coke handling experience becomes increasingly visual because of the loss of proximity. Instrumentation provides valuable feedback but is too indirect to portray some of the nuanced events that require prompt response.

Audio is near-essential. PSR has tried to provide a system which is reliable and low-noise. Multiple locations is helpful, particularly near the cone and mid-to-upper drum. Audio provides information which is not offered by any other instrument, including verification of clean drum, proximity to drum wall during cut, coke bed condition, etc.

Panel ergonomics should be a key deliverable because of the attention and static body posture required. Consider working with a coke cutting operator to design the panel.

Avoid replacing physical controls with HMI touch screen controls. Prevent requiring continuous pressure on a joystick, as this may invite 'creative solutions' by the user.
Key successful practices at psr - 2

Consider “serious controls” on human presence on the cutting deck during unheading and decoking. Routine human presence may come to be viewed as necessary, and reduce the benefit of the effort.

There are multiple examples of sites which have installed remote decoking only to use it with people on the deck and/or not to use it at all. It's clear that making this transition requires resolve; use it.

HMI graphics need to be simple to use, consistent, and well understood by the coke handler.

Agree on design and dynamic behaviour well ahead of the FAT, so that FAT testing can include complete graphics.

Consider hydraulic or electric winches.

Puget retained pneumatic winches because we had been successful with them and were already undertaking a substantial change. Other technologies may be more suitable for remote operation.
PAR DCU2 CEP

- This unit has all of the 1999 recommendations and more!
- World Class Delayed Coking Unit.
Safety – Remote Unheading

Bottom Z&J Unheading Valve – During Construction

Dual Cylinder Drive Rams
Safety – Remote Unheading

Top Z&J Unheading Valve – Post Construction

Blocking steam actuators staged positioned to prevent line of fire
Safety – Drum Switching
Safety – Drum Switching

- Deluge spray nozzles
- Blocking steam actuation positioned to prevent line of fire
- Valve direction arrows
MOV Operating Panel located to reduce line of fire and unnecessary climbing.

Maintenance Podium only allows raising and lowering of drill stem.
Safety – RUCCS User Interfaces

- Camera Monitors
- Acoustics Speaker
- Cutting Joystick
Safety – Coke Handling

Silo’s Eye View

Silos and Load Out Shelters
Design Improvements – Quench Water Storage Tank

- Drum overhead vapor is quenched using quench tower bottoms
- HHGO used as quench tower make up
  - Reduced natural recycle
  - More stable quench tower operation (due in part to quench water spray)
- Conical Bottom Quench Tank
- Four Mixing Nozzles
Motiva Port Arthur DCU 2

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