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"STATE-OF-THE-ART" DELAYED COKING STRUCTURE FOR FRONTIER REFINING

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"State-of-the-Art" Delayed Coking Structure for Frontier Refining

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Introduction

Over the last few years, Frontier Refining's facility in El Dorado, Kansas, USA, has undergone a major refinery reconfiguration to facilitate processing a greater proportion of very heavy crudes. A new vacuum unit was added and several of the existing units have been revamped for processing the heavier crude oil feed.

These refinery modifications produced significant constraints on the coker unit, due to the available coke drum volume. Frontier evaluated running shorter drum cycles, however review of the drum vapor velocity indicated severe foaming and carry-over would likely result.

In addition, coke drum reliability was decreasing because of frequent drum cracks. Frontier evaluated a number of options for repairing the existing drums, but most were deemed unacceptable due to the extended unit downtime that would have been required to complete the work.

CB&I had been advising Frontier on these drum evaluations, including the anticipated coke make increase. Frontier and CB&I concluded that the existing coke drums should be replaced with larger drums. In addition, as part of the revamp, Frontier continued its focus on best available technology for safely processing and handling coker materials.

Scope of the Frontier Delayed Coking Project

In 2006, CB&I was contracted to evaluate the existing coker to determine its suitability to process the new feed. With the exception of the coker feed preheat train, blowdown steam condensing, and the larger coke drums, the existing unit was capable of handling the new feed composition. CB&I and Frontier set the coke drum size based upon the new feed and Frontier's expected future expansion capacity: 26'-0" diameter and 70'-0" T-T. It was determined that the existing coke drum piping and valving would be acceptable for the new capacity, which set the scope of the new coke drum structure as follows:

- Two new vertical plate coke drums
- New foundation and elevated table top
- Steel structure
- Ruhrpumpen decoking system and new jet pump
- DeltaValve automated bottom and top unheading devices
- Piping, valving, and controls to tie the new drums into the existing coke drum isolation system

The new structures and remote cutting buildings can be seen alongside the existing drums in Figure 1. In addition, Frontier elected to install a coke handling and conveying system through a separate arrangement.

Fig. 1 – Completed Frontier El Dorado Coker Project, Alongside Existing Coking Structure

Features

The Frontier structure design continued the focus on operator safety and a low maintenance installation. One consideration of the design approach was to minimize the time for the operator to be on the structure during the coke cutting part of the cycle. The heavier feedstock to be processed by this unit is a known shot coke producer and therefore subject to blowouts. For this reason, removal of operating personnel from the structure was considered a necessity.

After considering several available technology features, the following were selected for the coker design:

- Vertical Plate Coke Drum™ Technology (CB&I patented design) – Gives longer coke drum life and is more tolerant to operating upsets.
- T-Rex skirt shell attachment (CB&I know-how) – For reduction of stresses in the shell to avoid shell cracks.
- DeltaValve unheading devices (bottom and top) – Industry accepted approach to removing operating personnel from the hazardous environment of the bottom and top head during the unheading step. Also, improves the efficiency of unheading step by decreasing the time required to unhead the drum, leaving more time for the other decoking steps. These devices also reduce ongoing unheading maintenance costs.
- Remote cutting station (Ruhrpumpen control system and DeltaValve control system) – Moves the cutter's station from the top deck and allows the unheading control of the drums to occur at a location off the coke drum structure.
- Auto switch cutting tool (Ruhrpumpen design) – Allows the operator to switch the tool from boring to cutting mode without having to be on the coke drum structure.
- State-of-the-art decoking control system – 100% electronic system.

Vertical Plate Coke Drum Technology

In the past decade, the demand for delayed coking capacity has been steadily increasing due to the financial benefits of processing heavier and lower-quality crudes. To keep up with this demand, many refiners with delayed coking units have chosen to shorten the heat up and cool down parts of the decoking cycle. This action, however, reduces the useful life of the coke drums.

This is because the severe operational thermal cycling causes the steel plate and the weld to be stressed with each cycle and due to their different relative strengths, the drum may bulge and eventually crack in the vicinity of the circumferential weld seams. This leads to the coke drums being taken offline to make needed repairs or partial shell replacements. While the industry recognizes that shorter, more severe cycles cause the bulging and cracking to appear sooner, few refiners have the option of increasing cycle time because of current refining economics.

Recent efforts to improve the reliability and life span of coke drums have focused on mitigating the stiffening effect of the weld seams, which increases stress and is chiefly responsible for the distortion and cracking phenomenon. These measures have included decreasing the weld metal yield strength to be within a closer percentage of the base metal yield, "blend grinding" the weld profile, using higher alloy clad materials to construct the coke drums, maintaining a uniform shell thickness throughout the coke drum (there are often step reductions in thickness from one shell course to the next based on each shell's specified design pressure), and specifying materials greater than two inches in thickness. Although several of these proposed specifications have indeed responded to some of the issues of thermal cycling, none of them have been effective in preventing coke drum distortion entirely.

In 1997, CB&I conducted its own analysis of the coke drum distortion and cracking problem, and concluded that the best solution would be to eliminate circumferential weld seams. Incorporating technology and know-how from other applications, CB&I developed a method for successfully fabricating shell plates with the long side oriented vertically. This process allows for the fabrication of cylindrical shell sections of up to 46 feet without a circumferential weld seam. Depending on plate size limitations, up to 70% of the circumferential weld seams can be eliminated, resulting in a cylindrical shell section that can endure the most severe thermal cycles (see Figure 2).

Fig. 2 – Elimination of Circumferential Weld Seams

Since 2000, CB&I has completed 11 Vertical Plate Coke Drum retrofit projects and six new coke drums, including two for the Frontier project. Frontier and CB&I chose the Vertical Plate Technology to take advantage of the improved reliability and life span.

T-Rex Skirt Attachment

Several alternative skirt designs have been developed to counter skirt weld failures. One such design is the T-Rex skirt (see Figure 3), which is a culmination of best practices and lessons learned from years of fabricating and repairing coke drums.

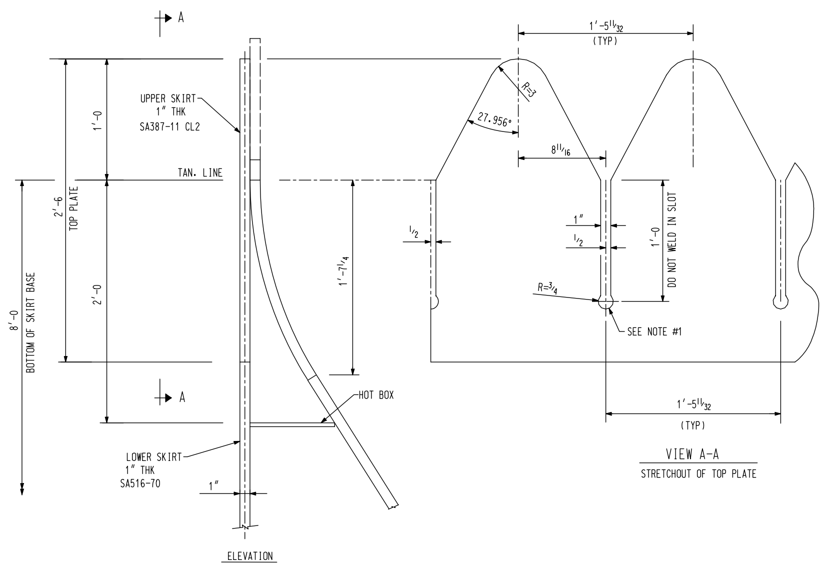

Fig. 3 – T-Rex Skirt Design

Recently, a Finite Element Analysis was performed on the T-Rex design, the results of which were compared to those for the conventional design configuration. This was a transient thermal analysis to establish the model temperature profile over the load cycle time history. The results of the thermal load tests showed that the T-Rex configuration has lower stress levels for the critical charge and quench thermal cycles. The T-Rex design was used on the Frontier coker project to take advantage of the reliability improvement (see Figure 4).

Fig. 4 – T-Rex Skirt for Frontier El Dorado Coker Project

DeltaValve Unheading Device

Bottom Unheading Valve

The bottom unheading device has substantially improved delayed coker design and safety. By creating a completely sealed connection from the bottom of the coke drum down through the discharge chute, the unheading device isolates personnel, equipment and the environment from exposure to hydrocarbons, hot coke, water and steam.

With the addition of the bottom unheading device, the following benefits are realized:

- Substantial savings in time, up to two hours, to implement the unheading and reheading portions of the decoking cycle.
- Reduced operating and maintenance expense.
- Fewer coke drum operators.
- Operators are not required to be on the structure when the drum heads are removed.
- The bottom DeltaValve device also has throttling capability so as to not overwhelm the primary crushing and transportation systems.
- The deck design provides substantial open area that benefits operator safety and ease of maintenance.

For the Frontier project, the bottom unheading device is supported by a dual purpose monorail system. While the primary function is to support the weight of the unheading valve, the monorails were extended to allow the removal of the unheading valve from the unit without the need of any assistance crane. The open design and monorail system of the bottom unheading valve can be seen in Figure 5.

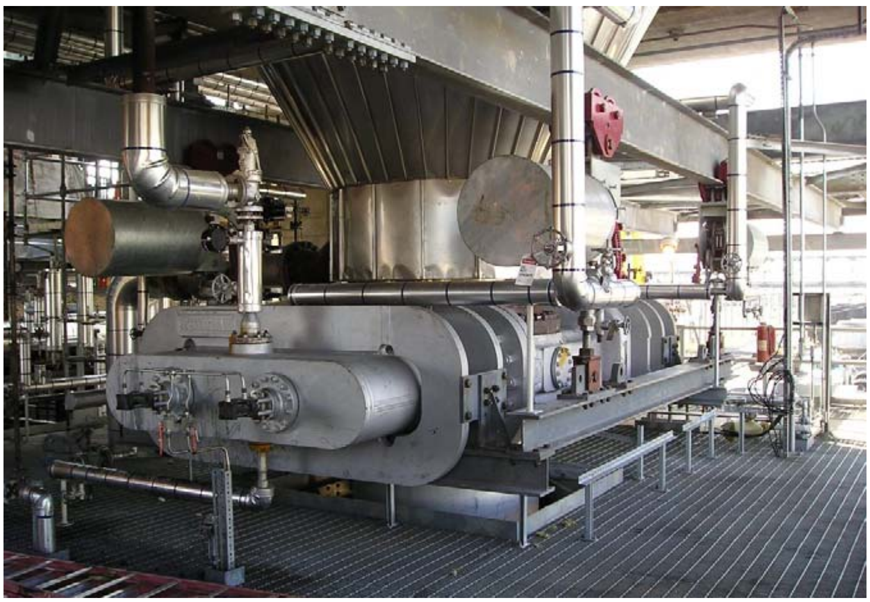

Fig. 5 – Frontier’s Bottom Unheading Valve, Deck and Monorail System

Top Unheading Valve

The traditional approach to top unheading, as with bottom unheading, was a labor intensive activity. The operators working on the top head were exposed to upsets within the coke drum expelling hot steam, fumes and coke. With the top head of the Frontier coker connected to the containment dome which is vented to a more remote location, operators' exposure to coke drum upsets is reduced.

Remote Cutting Station

The remote cutting shelter consists of two buildings (Figure 6), one containing the control panels and camera monitors for the operator to unhead and decoke the drum and a second to house the I/O panels, variable frequency drives and PLC. The operator shelter is centered facing the chutes to physically observe the coke leaving the drum.

Fig. 6 – Remote Cutting Buildings

The interior of the cutting shelter consists of two sets of panels, one for each drum, controlling the decoking equipment. The cutting shelter also houses the DeltaValve top and bottom control panels. Also included are readouts for coke drum acoustics and vibration, that the operator uses to determine when the coke drum wall is reached, as well as the camera system located on the structure.

The camera system is composed of four tilt and pan cameras that are operated from the cutting shelter. These cameras have low light, zoom and panning capabilities if required by the location. Two of the cameras are located near grade to provide views where the coke chutes are located.

These cameras are situated to provide two additional angles to prevent a loss of line of site in case of heavy steam in one direction due to the prevailing winds. A third camera is located in the top unheading deck to provide general monitoring of the area as well as the location of the cutting tool and the rotation of the drill stem. The fourth camera is located approximately half way up the derrick structure with the primary function of providing a view of the rotation of the hoist/cable. Figure 7 shows the camera display for the operator.

Fig. 7 – Cutting Shelter Camera Display

Auto-switch Cutting Tool

The auto-switch cutting tool allows the operator to switch from boring mode to cutting mode without the need to remove the cutting tool from the drum. The switch is done by cycling the pressure to the cutting tool. Properly used, this enhances operator safety by not requiring operator presence on the structure with a full coke drum open to the environment. This operation is performed very quickly, thereby providing time for use in other steps in the decoking cycle.

Cutting Tool Floating Containment Dome

The cutting tool floating containment dome has several advantages, including:

- Self alignment of the drill stem guide to centerline of the derrick to compensate for any banana effect. Reduces potential of a stuck tool due to cutting tool/drill stem channeling.
- Centering of drill stem guide with dampening springs to reduce impact from blowouts.
- A permanent parking place for the drill stem and cutting tool when the drum is in the coking cycle. The stem does not have to be tied off when not in use.

- The dome acts as a venting chamber for fumes that are expelled when the top head is opened and to dissipate heat during the coking cycle. The dome is vented to a more remote location.
- Containment for coke pieces that are expelled during a blowout.

Figure 8 shows the containment dome with the drill stem parked. The line from the side of the dome is the vent, which is directed to a remote location. The dome itself is mounted directly on the top DeltaValve unheading device.

Fig. 8 – Cutting Tool Floating Containment Dome

Decoking System

The decoking system supplied by Ruhrpumpen is a totally electronic control system that is electrically powered. The hoist and drill stem drive are both electric motor driven. This eliminates the intermediate step of a hydraulic power unit or pneumatic driven equipment. The electric-drive electronic-control nature of the system facilitates the ability to control the decoking system remotely. Also included in the system is a stem free-fall arrestor. Figure 9 shows the electric motor driven hoist while Figure 10 shows the electric motor driven drill stem drive.

Fig. 9 – Decoking System Hoist

Fig. 10 – Decoking System Drill Stem Drive

Conclusion

The Frontier El Dorado delayed coker now has many of the most reliable and safe features available in the industry. Since its start-up in mid-2008, the unit has achieved its desired design cycle times and is capable of additional throughput.