EPA/OSHA Chemical Safety Alert/Safety and Health Information Bulletin - Hazards of Delayed Coker Unit Operations

Purpose

The Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA) are jointly issuing this "Chemical Safety Alert/Safety and Health Information Bulletin" (CSA/SHIB) as part of an ongoing effort to protect human health and the environment by preventing accidental chemical releases. EPA and OSHA select topics for CSA/SHIBs from recognized scientific, industrial hygiene, labor, industry, engineering and/or medical sources.

EPA and OSHA believe that addressing the hazards of Delayed Coker Unit (DCU) operations is necessary based on the importance of DCUs in meeting energy demands, the array of hazards associated with DCU operations, and the frequency and severity of serious incidents involving DCUs.

EPA and OSHA strive to:

- better understand the causes and contributing factors associated with accidental chemical releases and to prevent their recurrence; and
- provide information about occupational hazards and noteworthy, innovative, or specialized procedures, practices, and research that relate to occupational safety and health and environmental protection.

Regulatory actions can not prevent all chemical accidents. Therefore, understanding the cause of accidental chemical releases, widely disseminating the lessons learned, and integrating these lessons into safe operations will help prevent chemical accidents.

This joint EPA and OSHA CSA/SHIB supplements active efforts by refiners and industry associations to exchange DCU fire and safety technology and to increase awareness of environmental and occupational hazards associated with accidental chemical releases. It is important that facility operators, State Emergency Response Commissions (SERCs), Local Emergency Planning Committees (LEPCs), emergency responders, contractors, employees, and others review this information and take appropriate steps to minimize the risk of accidental chemical release.

When using this document, please be aware that:

- This document does not substitute for EPA or OSHA regulations/standards/rules, nor is it a regulation/standard/rule itself. It cannot and does not impose legally binding requirements or obligations on EPA or OSHA, states, or members of the regulated community. Rather, it is advisory in nature, informational in content, and intended to assist interested parties in addressing potentially hazardous or unsafe conditions and situations.
- The guidance provided in this document does not represent final agency action and may change in the future, as appropriate.

The measures described in the CSA/SHIB may not apply to every possible situation, given the potentially unique or unusual circumstances associated with a particular plant, process, operation, or facility.

Problem

In recent years, DCUs have experienced a number of serious accidents despite efforts between many refiners to share best practice information, related to DCU safety and reliability.

Background

DCUs provide a difficult but increasingly important function for the refiner. The DCU, unlike other petroleum refinery process operations, is a semi-batch type operation. That is, one part of the process is a batch type operation while the remaining portion is a continuous operation. It is the batch portion of the operation (drum switching and coke cutting) that causes unique hazards and where most serious accidents occur. The continuous portion of the operation (fractionation and drum charge heating) is generally similar to other refinery operations and is not further discussed in this document.

Drum switching frequency typically ranges between 10 to24 hours. While one drum is filling, "on oil", the alternate drum, "off oil", is cooled with steam and water, opened (unheaded), and decoked. Finally, the "off oil" drum is closed (reheaded), purged of air, leak tested, warmed-up and placed on stand-by, ready to repeat the cycle. (See Figure 1).

The quality of available crude oil has declined as supplies of lighter crude oil, which contains shorter chain molecules, is used up. Current crude oils tend to have more long chain molecules, known as "heavy ends" or "bottom of the barrel." The heavier ends may be separated out and sold as a relatively low value industrial fuel or to asphalt tile manufacturers, or they may be further processed to yield higher value products. The most popular process for upgrading the heavy ends is the DCU, which is a severe (high temperature for an extended period of time) form of thermal cracking. This process produces higher value liquid products and leaves a solid carbonaceous residue called "coke."

In delayed coking, the feed material typically is the residuum from vacuum distillation towers. The feed material is heated to 900 to 930°F at about 60 to100 pounds per square inch gauge (psig) then discharged to the bottom of one of the coke drums where cracking proceeds. Typical drum overhead pressure may range between 15 to 35 psig. Feed leaving the heater cracks and cools in the transfer line yielding a typical coke drum inlet temperature of 870 to 910°F. As the cracking process takes place, the lighter products produced exit as vapors from the top of the drum, leaving a solid residuum of coke in the drum. The vapors are sent to a distillation tower for separation into gas, gasoline, and other higher value liquid products.

After the coke in the coke drum has reached a predetermined level, the heater discharge is diverted to the alternate drum to maintain a continuous heater operation. The filled drum is steamed to strip out any remaining vapors, cooled (quenched) with water, drained and unheaded in preparation for decoking, which consists of fracturing the coke bed with high-pressure water jets ejected from a rotating cutter.

About 53 DCUs were in operation in the United States in 2003, in about one third of the refineries.

DCU Specific Safety and Health Hazards of Concern: Factors that contribute to the hazards associated with DCU operations are listed below and discussed in additional detail:

- Manpower Intensity (Equipment Handling Tasks) and Emergency Evacuation
- Mistaken Equipment Identity Hazard
- Coke Drum Head Removal
- Coke Cutting – Hydroblast System
- Coke Transfer, Process, and Storage
- Thermal Stress on Coke Drums
- Toxic/Health Exposures and Burn Trauma

1. **Manpower Intensity and Emergency Evacuation** – The delayed coking process is very manpower intensive and the height of the structure on which work is done impedes rapid emergency escape. Each batch process cycle requires 25 or more operations. Also, many DCUs operate with six or more drums.

   Tasks are performed at several levels on the coke drum structure. The upper working platform (frequently called the Cutting Deck) is generally well over 120 feet above ground. In case of an emergency. evacuation from the structure can be difficult.

   In cold weather, moisture escaping from the drum openings may cause fog, which can obscure vision as well as make walking and working surfaces and hand rails slippery.

Recommendations:

- Ensure that the number of persons permitted on or under the coke drum structure during sensitive tasks such as drum unheading or coke cutting be kept to an absolute minimum.
- Review the location and suitability of emergency escape routes. Protected stairways, preferably detached from the coke drum structure, are the most effective conventional means of emergency egress from tall structures such as those serving the coke drums. Horizontal walkways to adjacent structures should also be explored. Some refiners are considering commercially available escape chutes.
- Establish or verify the operability of an emergency unit evacuation signal (Scram Alarm) to expedite clearing the structure of personnel if a problem develops. Alarm signal actuation (triggering) stations should be deployed at selected points in work areas and along the egress routes.
- Incorporate fire/heat intensity control water sprays and/or curtains into the fixed fire suppression system to protect workstations and emergency egress routes.
- Provide heat shields to protect work stations and escape routes. Be sure that the shield will not interfere with egress and that it will not entrap fugitive vapors.
- Conduct emergency evacuation simulation exercises to ensure familiarity with emergency signals, evacuation routes, and procedures.

2. **Mistaken Equipment Identity Hazard** – Most DCU modules alternate (switch) between two (but occasionally three) coke drums. Each drum has its own set of very similar valving. Furthermore, there are usually several modules, frequently with similar valving. Activating the wrong valve or switch because of mistaken identity has caused serious incidents.

Recommendations: No one system has proven effective in eliminating activation of the wrong valve or switch due to mistaken coke drum or module identification. However, the following actions have been reported as beneficial:

- Conduct human factors analysis to identify/evaluate control of potential operator actions which may affect the safe operation of the coke drum system.
- Provide interlocks for automated or remotely activated switching valve systems.
- Explore the possibility of interlocks for large valves normally turned as part of the switching/decoking cycle to avoid unanticipated valve movement.
- Color code and clearly label valves and control points to guard against incorrect identification.
- Provide colored-warning lights at valve and switch stations to help the operator determine which drum is in service.
- Use the "buddy" system to help verify accurate valve or switch identification.
- Conduct periodic and documented training on the importance of activating the correct valve or switch, and the consequence of incorrect activation.

3. **Coke Drum Opening** – Steam stripping and/or water quenching, performed in preparation for drum opening, may follow established channels through the coke rather than permeate through fissures into most of the coke mass. Since Coke is an excellent insulator, this can result in isolated hot areas within the block of hot coke. These hot pockets have resulted in a geyser of steam, hot water, coke particles, and hydrocarbon emitting from either or both drum openings after removing the heads. Such geysers or eruptions typically occur when water contacts very hot coke that has become encased in partially coked resid near the top of the coke bed. Also, undrained hot water released during bottom head removal can present a serious threat to personnel. Although infrequent, eruptions have been attributed to a combination of improper drum drainage *and* the existence of a hot spot *and* a shift or partial collapse within coke bed.

- Under abnormal situations, such as feed interruption, steaming or quenching anomalies, hot spots may persist in the drum. In some cases, "hot tar balls" form in the drum, allowing a mass of hot (over 800°F) tar-like material to rapidly eject from the bottom head opening.
- Sometimes the coke forms into a multitude of individual, various sized, spherical shaped chunks, known as "shot coke", rather than as a single large mass. In this situation, the drum contents can be released (dump) from the drum out of control when the bottom head is removed. An avalanche of shot coke can pose a serious hazard to anyone in its path.
- Some DCUs require the removal of platform sections to accommodate unheading the bottom of the drum. This may introduce a falling hazard.

Recommendations: It may be difficult to anticipate the presence of either a hot spot or a hot tar ball that may have eluded the steam purging and/or water quenching. It is prudent to:

$ Always assume the possibility of a hot spot-induced geyser when unheading a drum and during coke cutting operation. This should include staying in a protected area to the extent possible and preparation for rapid evacuation and activation of the fire suppression system from a safe remote location.

$ Make provision for temporary guardrails while platform plating is removed to facilitate bottom head removal to protect employees from falling.

$ Consider an emergency cooling water source in the event of a loss of primary steam/cooling water supply or drum inlet flow path obstruction.

$ Consider a top head vapor ejector to further enhance top head safety for personnel.

$ Consider automating both top and bottom head removal to move workers away from these exposure areas.

Develop an abnormal situation action plan to address <u>any</u> type of operating anomaly noted, such as during drum charging, steam stripping, or water quenching. The procedure should include provision to:

$ Immediately defer drum unheading

$ Halt coke cutting action

$ Conduct a thorough technical assessment of the situation and formulate a situation specific action plan.

4. **Cutting Coke From Coke Drum – Hydroblast System** -- Serious incidents that have occurred in connection with hydroblasting operation used to cut the coke out of the coke drum. Some of the consequences include: (See Figure 2)

   $ High-pressure (2000 to 5000 psig) water was not shut off before the cutting nozzle was raised out of the top drum opening, allowing water jets to eject into the top deck work area.

   $ The water hose burst while under high pressure.

   $ The wire rope parted, allowing the drill stem, water hose, and wire rope to fall.

   $ Gantry damage, particularly while extracting a stuck drill stem.

Recommendations

- Consider an enclosed cutter's shack for personnel protection, preferably supplied with air from a remote source to maintain a slight positive pressure.
- Establish and enforce procedures to prevent personnel entry into areas that may be in the path of a geyser.
- Ensure that personnel who must be on the coke drum structure wear prescribed personal protective equipment.
- Establish and verify the operability of the automatic interlock to shut off and prevent restart of the cutting water pump any time the cutting head is raised to the predetermined cut off point within the coke drum. Redundant, independent switches may provide an additional level of protection against extracting the cutting head while under pressure.
- Establish and verify the adequacy of the inspection program for the cutting water hose.

- Verify that the gantry structure has not been weakened due to corrosive conditions, such as mist exiting from the top nozzle. In such cases, the hoist may be able to cause a pull that exceeds the strength of the weakened gantry.
- Establish and verify the adequacy of the wire rope and hoist inspection and maintenance program.
- Establish and verify a procedure for extracting a stuck drill stem without over stressing the wire rope or gantry.
- Consider the use of drill stem free fall arrestors.

5. **Coke Transfer, Processing, and Storage–** Open mechanical conveyance systems that have presented safety or health hazards are listed below:
   - The movement of rail cars while being repositioned by small locomotives or cable tuggers to receive the coke as it is being cut from the drum.
   - Mechanical and sluice type (hydraulic) conveyors have presented personal injury exposures.
   - Similarly, coke crushers used to break up large chunks of coke pose personnel injury exposure.
   - Spontaneous ignition fires are not uncommon in moist, high sulfur content coke piles and in rail cars.
   - Fugitive mists and vapors from the cutting and the quench water contain contaminants that can pose a health hazard. (See Item 7 –Health/Toxic Exposures)
   - Wet coke contained in an enclosed area is known to have absorbed oxygen from the enclosed atmosphere, leaving the area oxygen deficient and incapable of life support.

Recommendations:

- Designate and enforce "Keep Out" areas to prevent personnel entry where heavy equipment movement may take place and out of the possible lash path of a failed equipment movement wire rope.
- Establish and verify an alarm system to activate immediately before and during heavy equipment (rail car, bridge crane) or conveyor movement.
- Anticipate possible spontaneous combustion fires where granulated coke or coke dust has accumulated.
- Establish personnel protective measures to protect against inhalation or personal contact with mists from water used for cutting, quench or hydraulic movement of coke that may contain contaminants. (See Health/Toxic exposures)
- Establish or verify the conformance of entry prevention procedures into any enclosed area or vessel where coke, particularly wet coke may be present.

6. **Thermal Stress on Coke Drums** – A drum sometimes develops cracks and bulges as a result of the severe thermal shock experienced during each cycle. This thermal shock is caused by repeated rapid heating followed by quenching (rapid cooling) of the drum. The phenomena of Low Cycle Fatigue (LCF) is attributed to repeated thermal shock.

Recommendations:

- Maintain state-of-the-art metal inspection programs to identify needed repairs and monitor remaining drum life. Reference 1 of the attached list of additional reading provides an overview of inspection methods.)

7. **Toxic/Health - Exposures and Burn Trauma** – The potential exists for the following toxic/health exposures:

- Hazardous gases such as hydrogen sulfide, carbon monoxide and trace amounts of polynuclear aromatics (PNAs) associated with coking operations may emit from an opened drum or be entrained in the coke after it has left the drum.

- Recycled water used in quench and hydroblasting operations may be highly alkaline and contain oil. Sulfides and ammonia, and/or phenol may also be present in the recycled water.
- If heavy metals (e.g. vanadium) are present in the feed stock, they are likely to also be present in coke dust around DCUs.
- Heat stress may be a health hazard during warm weather, particularly for those required to wear protective clothing while performing tasks on the coke drum structure.
- Hot water or steam escaping from a coke drum can present a serious burn trauma. Liquid hydrocarbon (black oil) escaping from the drum may be well above its ignition temperature. Even if the oil does not ignite, contact with black oil can cause second or third degree burns.

Recommendations:

- Double block and steam seal isolation configuration will reduce the likelihood of unanticipated leakage into or out of the coke drum.
- An industrial hygiene survey should be conducted to evaluate health exposure potential and establish appropriate protective measures.
- Establish burn trauma response procedures, including interaction with the emergency medical service provider and the burn trauma center to be used in the event of a burn incident.
- Conduct burn trauma simulation exercises to verify the adequacy of the emergency response procedures and the training level of the involved personnel.

8. **Suggested Internet resources:** - The search entry, "Delayed Coker Unit", leads to many sources of information. The following are examples of informative additional reading.

1. http://www.cia-inspection.com - addresses coke drum mechanical integrity and life improvement. A comprehensive list of technical papers is included. Also included is an overview of drum metal inspection methods and a discussion of Low Cycle Fatigue.

2. http://www.coking.com - focuses on coking best practices, safety, reliability, and communications within the DCU industry.

3. http://www.fireworld.com/magazine – describes a May 1999 coking unit fire and offers recommendations on fire protection.

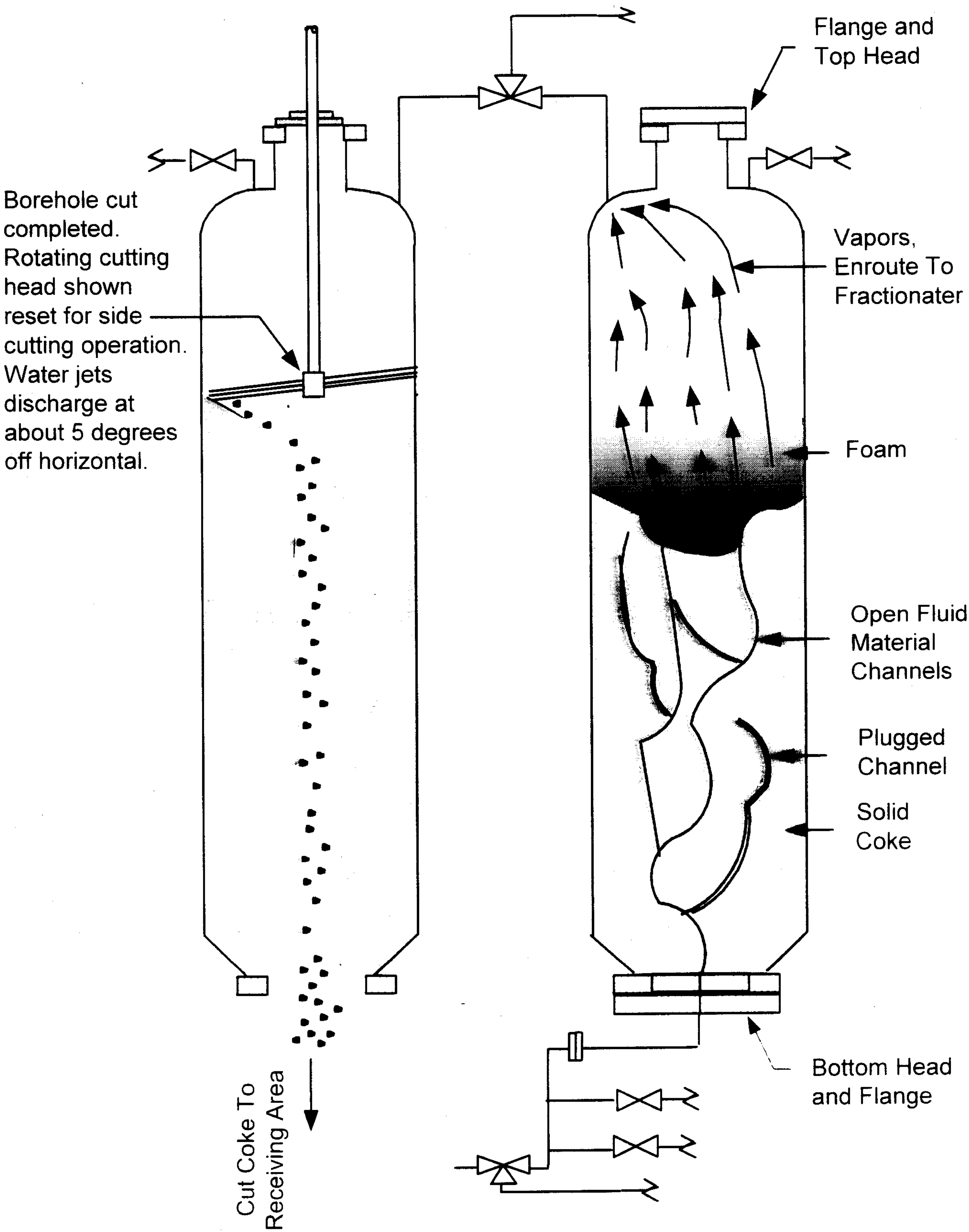

Figure 1 - Delayed Coker Unit
Cutaway to Depict Coke Cutting (Left) and Filling Migration (Right)

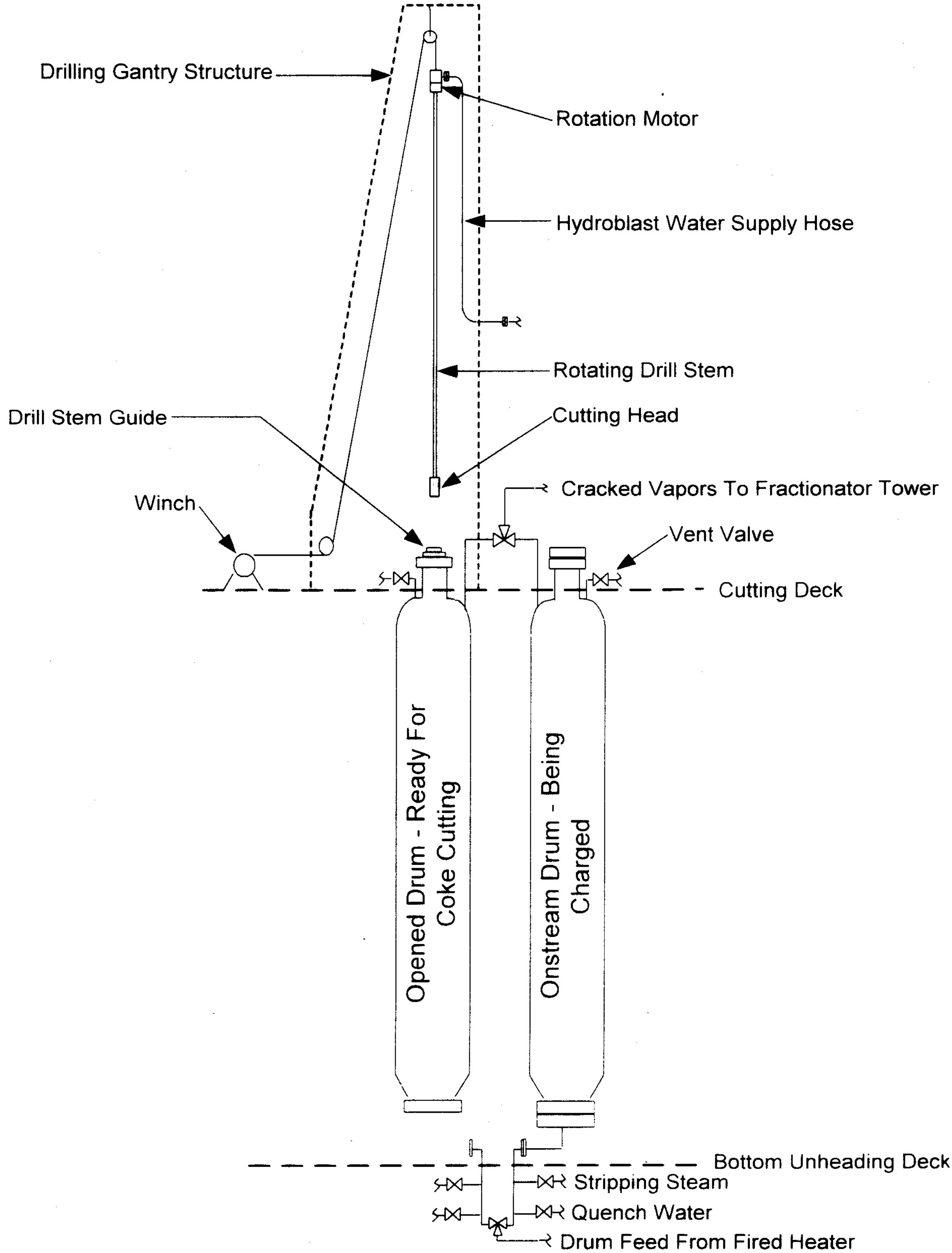

Figure 2 - Delayed Coker Unit
Coke Drums and Hydroblast Systems