Using HAZOP to address the problem of repeated plant accidents: Delayed Coker Units

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In this paper, the second in our series on repeated accidents in Process Plant, we discuss accidents during operation of Delayed Coker Units. Our paper argues that to learn the lessons from past accidents it essential to understand which risk controls have failed and why. Only then can additional prevention measures be proposed and implemented to prevent repeated accidents.

We discuss three separate accidents at Delayed Coker Units

- A multiple fatality accident which occurred during drum un-heading
- A major fire which occurred when safety interlocks were bypassed
- A fire which occurred due to unintended discharge of hot hydrocarbon to drain

In each case we will show, using examples from our own work, how the hazard at the root cause of the accident can been recognized during HAZOP study. This paper will give examples of HAZOP discussions showing how the potential hazard was introduced and the recommendations made by the HAZOP team after the ensuing discussions. We will also discuss the implementation of these recommendations and the benefit of instilling a sense of proximity in those immediately responsible for plant safety especially those enacting administrative controls. Techniques will be described which aim to convert the safety procedures envisaged during HAZOP into operations safety instructions applicable throughout the life cycle of the plant.

Introduction

This paper introduces three accidents which occurred on Delayed Coker Units (DCU) but our intention is wider than discussing operational issues of concern to the specialists who manage the safety of DCUs. The main narrative of this paper addresses repeat accidents and tries to explore why they occur and what can be done to reduce the frequency of recurrence. It forms one in a series of papers which focus on eradication of the "unknown known" as a risk category in process safety management. Taking the description from the four part categorisation of risk by Donald Rumsfeld (1) we earlier identified accidents whose causation is known in the industry but which has gone unrecognised and therefore uncontrolled in the affected plant (2). These are conditions which are known in the industry but were apparently unknown to those operating the plant and who therefore allowed history to repeat itself often with tragic and avoidable consequences.

One approach is to pick out particular types of equipment and discuss accidents which have occurred and we have already published one paper of this type which focussed on accidents at pumps. Another approach is to focus on particular types of process plant and in this paper we apply this second approach taking as our example Delayed Coker Units.

Throughout this paper we try to give practical examples of ways to strengthen HAZOP studies to ensure they identify the potential for accidents which have occurred elsewhere to recur in the design under review. We are concerned that this information accumulated in the design and EPC phase is transferred effectively to operations staff and advocate the use of Operational Safety Instructions as a suitable method. It is important that lessons learnt from accidents elsewhere are used to strengthen the safety management system and reduce the risks in the plant under review. Risk reduction may take the form of engineering controls, safety interlocks for example, but equally important is the plant safety culture and the way administrative controls such as permits and procedures are organised and audited. As in previous papers we argue for developing a sense of Proximity so that those immediately affected internalise a corporate memory of the lessons learned from the past.

Accident 1: Bottom Un-heading Device (BUD)

A multiple fatality accident occurred during a drum un-heading which was undertaken in an attempt to recover from a process interruption. Such interruptions may mean that insufficient temperature is reached to allow the coking reaction to complete allowing unconverted vacuum residue to accumulate in the coke drum. Apart from inadequate temperature control such situations could occur if there were for example, a leak followed by ignition and fire during the start of the coking cycle or a power failure once it had commenced. The following HAZOP discussion records such a potential hazard resulting from heater trip early in the cycle.

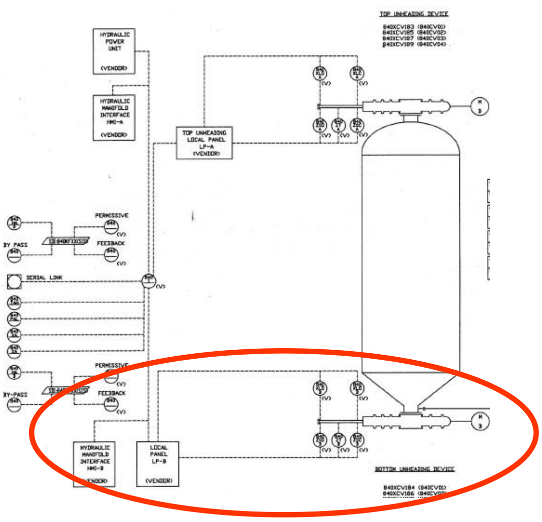
Causes	Consequences	Safeguards	Recommendations
2. High flow of steam when furnace is tripped.	1. Potential for tar ball if the heater is tripped early in the coking cycle. 2. If it is tripped late in the cycle increase velocity in the coke drum results in potential for foaming into the fractionator bottom.	1. A small foam over can be managed by frequent filter change on the fractionator bottoms.	

or inadequate temperature control for example in case of instrument failure

Causes	Consequences	Safeguards	Recommendations
1. FC26 opens e.g. loss of instrument air, or misset in manual or operator opens the glove valve on the bypass too much (when control valve in maintenance).	1. Lower temperature from TIC61 on outlet of pass will increase in firing in the affected cell. 2. Master controller will reduce the flow to the other 3 passes and TC control on the outlet will reduce the firing in these cells. 3. Potential for increased skin temperature on the tube receiving high flow. 4. Potential for enhanced coking rate in the affected tube.	1. If the affected pass does not reach the coking temperature TAL from T167 warns the operator if the combined flow temperature is sufficiently low for tar ball to form in the coke drum. 3. If there is sufficient heating to maintain coking temperature, at high flow the vapour velocity from the coke drum into the fractionator rises. Also the coke drum fills up faster and there is risk for foam over into the fractionator. The operator is warned of the situation in the coke drum by the nuclear level detectors allowing him to make appropriate action either switching to the other drum or going to drum bypass.	R199.1 Develop operating procedures to manage emergency situations such as suspected tar ball in the coke drum.

At the accident site such a situation had arisen as a result of a leak and fire at the start of the coking cycle and the unit was shut down using the normal procedure which resulted in a half filled coke drum containing a mixture of oil and water. Attempts to drain the drum failed when the drain became plugged with unconverted vacuum residue. In a further attempt to drain the drum, the operators tried to slacken the lower head bolts in the hope that a flow of oil and water could be directed into the coke pit. This operation also failed and it was decided to completely remove the bottom head. During this operation, a large amount of oil and water was released; flooding the unit and requiring a lengthy clean up. The recommendations from the subsequent inquiry into the incident included installation of remote un-heading and better procedures for managing drums that may contain unconverted vacuum residue (tar) (analogous to the recommendation in the HAZOP record reproduced above). Despite these recommendations, no changes were implemented.

Two years later a similar situation developed during a power failure and there were no facilities or procedures to manage the half-filled coke drum. Attempts were made to steam strip the drum but these failed as the drum inlet was plugged. There were no indications of drum internal temperature, just drum external skin temperatures. Operators suggested quenching the drum with water, but were over-ruled (perhaps recalling the clean-up required the last time this situation occurred). Instead it was decided to un-head the drum starting with the top head which was successfully accomplished by operators using breathing equipment. The lower head was unbolted in a similar manner and hydraulic controls, (cylinders) were used to start lowering the head. A cloud of gas ignited upon release followed by a mass of hot unconverted vacuum residue which also burst into flames. Despite a fast emergency response, 6 people were killed, two operating the un-heading device and four standing by to assist with any clean-up which might be required.



The accident emphasises the need for procedures to safely handle tar drums. Designers of delayed coker units stress the use of a slide valve for bottom un-heading as well as remote operation from a position offering the operator protection from hot discharges including steam, water and coke. Operational procedures are required to ensure a complete quench of the coke drum and to minimize hot spots. Detailed operating procedures are required to eliminate the potential of making a tar drum. These procedures should include the proper instructions to handle an unconverted tar drum in the unfortunate event it becomes necessary.

Procedures must be in place to restrict all non–essential personnel from being on the structure during the drum unheading and decoking. Operators are to be in a remote structure (enclosure) during these activities. Most Delayed Cokers built today include remote un-heading and decoking facilities located at ground elevation.

Identified hazards and subsequent recommendations must be implemented immediately to reduce operating risks. A thorough understanding of these procedures developed to reduce risks must be understood and adhered to by the operators. This fundamental understanding will help the operators make the correct decisions when faced with unit upsets or equipment failures. Operational convenience cannot be included as part of the decision making process.

Accident 2: Top Un-Heading Device (TUD)

The second accident described occurred not at the bottom head but at the top head of a coke drum. Five workers were injured when the top head of an on-line coke drum was inadvertently opened in error. Hot hydrocarbons erupted and ignited when exposed to oxygen. One of the injured workers was admitted to the hospital as a result of this incident.

Modern delayed cokers are configured with interlocks which are intended to prevent operating errors of the type. HAZOP studies examine such interlock sequences and may recommend changes as illustrated in the following extracts.

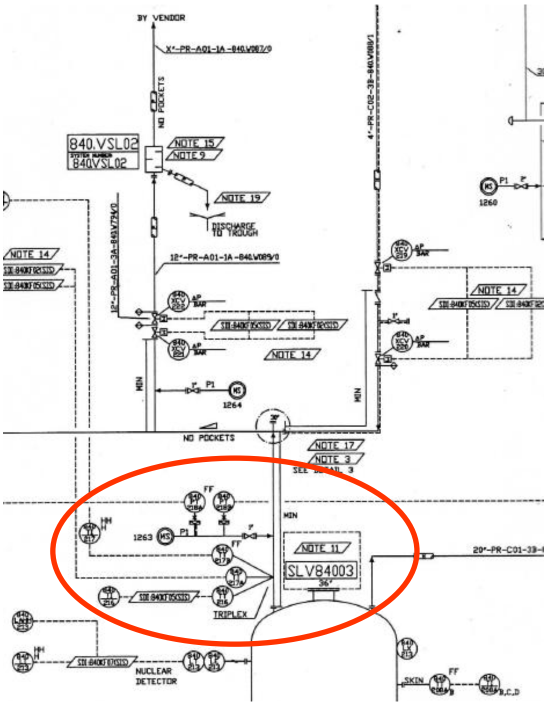
Causes	Consequences	Safeguards	Recommendations
4. Outlet of the coke drum is blocked e.g. XCV101 or XCV102 or XCV3 closes.	1. Potential for overpressure in the coke drum.	1. PSV 1A/B on the coke drum (sized for blocked outlet with spalling and quenching on the coke drum discharge). 2. XCV3 A has a mechanical stop preventing complete closure. 3. Interlock logic prevent from XCV101 and 102 closure.	R248.2 Provide update of Cause & Effect Diagram so that the permissive to open XCV101 or 102 is closed of slide valve (not “not open” as shown on the cause and effect diagram).
	2. In current design it is currently possible to close XCV101 or XCV102 during normal coking mode.	1. PSV 1A/B sized for blocked outlet on the overhead line while the drum is in coking phase. 2. Interlock for preventing the closure of XCV101 on overhead line during normal operation (coking) has not been provided by licensor.	R248.3 Evaluate preventing closure of SP1 or SP2 through error while coke drum 1 is in coking mode (SV 1A/B are sized to provide relief for this case, the concern is that when the SV lifts there may be high foam formation allowing foam over into the blowdown system requiring unit shutdown for cleaning). Recommendation is made to avoid the consequent B.I.

Causes	Consequences	Safeguards	Recommendations
4. Operator tries to open the unheading valve locally (directly on the actuator), either on the correct or the incorrect coke drum.	1. Potential for release of hot hydrocarbons to atmosphere followed by fire (scenario is much worse if operator acting on incorrect coke drum).		R. Ensure that the permissive to open top and bottom unheading devices cannot be bypassed in case of local activation (i.e. directly from the actuator). Also, if the electrical signal is lost (e.g. in case of loss of power) ensure that the systemwill be put in safe mode and movement of top and bottom unheading devices will be inhibited.

Causes	Consequences	Safeguards	Recommendations
1. Operator closes the top slide valve while the drill stem is in position.	1. Potential damage to the slide valve and the drilling facility.	Details of the interlock on the drill/cutting tool not available (see R551).	R548.1 Evaluate if interlock is provided to prevent closing the top slide valve until the drilling system has been withdrawn as part of vendor HAZOP.

Causes	Consequences	Safeguards	Recommendations
1. Operator tries to open the top and bottom unheading devices on the coke drum in coking mode by mistake.	1. Large release of hot hydrocarbons to atmosphere, leading to fire and operators' exposure.	1. Permissive to open top unheading valve is subject to the following conditions to be met (Logic XYZ): - coke drum pressure below 0.014MPag - vent valves in an open position - quench oil valves in a closed position - valve on the relief route of PSV- in a closed position - ….. 2. Requirement for the vendor of unheading devices to provide mechanical pin for both top and bottom unheading devices. Removal of the mechanism pin will be permissive for the opening of the relevant unheading device.	R.19.379.1 Consider additional permissive for the opening of the top and bottom unheading devices (logic XYZ), requiring that the coke drum temperature must be below 149C.

The accident investigation subsequently recommended a number of design and procedural changes to add additional layers of protection to reduce the risk of incorrect un-heading device operations.



Designers of Delayed Coking Units have long recognized the need for a combination of protective layers including Design details, Operational Techniques and Operating Instructions.

Specifically relating to the accident described above, a local control panel used to control the top unheading device should have been located in a remote location providing the operator safety protection. Properly configured interlock schemes should be installed to ensure all permissives required are met prior to operating (opening) the Top Unheading Device (TUD). Many refiners prefer to automate the entire valve sequences required of a structure operator. This can include the coke cutting and loading of coke into the coke handling system.

No one is allowed on the structure during these critical steps. The operator can perform the needed task from a remote shelter in a safe location. Special considerations can be given in emergency situations with the proper permitting and management of the people involved. But it is essential that these situations are handled by experienced operators fully conversant with the fundamentals of the process and with Process Safety rather than operational convenience foremost in mind.

Accident 3: Error at drain

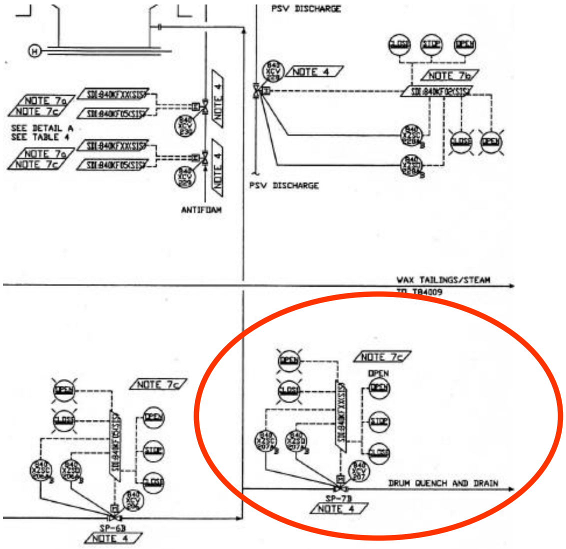
In the third accident, hot hydrocarbon was discharged to an open sewer from a 1 ½" drain valve in a transfer line left open in error at the start of a coking cycle. The hot fluid ignited and exploded shortly after the fire brigade was called. Three men were killed as a result of this incident. Such accidental discharges to drain are often identified in HAZOP studies.

Deviation	Causes	Consequences	Safeguards
Temperature - High	Normal operating temperature 353°C is well above autoignition temperature.	1. Potential for fire in case of leakage.	1. XV provided to isolate the fractionator in case of leakage from downstream drains.

Deviation	Causes	Consequences	Safeguards
Loss of Containment	2. Line to oily water sewer left open in error.	1. Release of fractionator bottom products above its auotignition temperature and potential for fire.	1. XV provided to isolate the fractionator in case of leakage from downstream drains.

Causes	Consequences	Safeguards	Recommendations
4. Operator error opening valves on the drain line to coke pit when steam is being routed to the coke drum.	1. Release of steam in the coke pit area with potential exposure of operator (burns). 2. Potential for reverse flow of hydrocarbon from fractionation column and coke drum towards the coke pit (this depends, among other things, on the length of the drain line to the coke pit).	1. Given the operating pressure in the coke drum reverse flow of hydrocarbons towards the coke pit along utility line when steam is injected is not considered credible. 2. Even in case of some hydrocarbons being routed to the coke pit it is expected to be diluted by the steam.	R. Consider provision of permissive for valves on drain line to coke pit such that they can only be opened if valves on the vapour line to the fractionator and valves on the vapour line to the blowdown tower are in a closed position. This is to make sure that the coke drum is fully isolated from the process (i.e. from upstream heater and downstream fractionator and blowdown tower).
			R. Ensure that the following are provided in the proximity of the coke pit/pad, coke settling maze and sump, as appropriate: - Hydrocarbon detectors - H2S Detectors - Fixed fire fighting facilities Also ensure that operators working at or near this area wear carry personal H2S detectors.

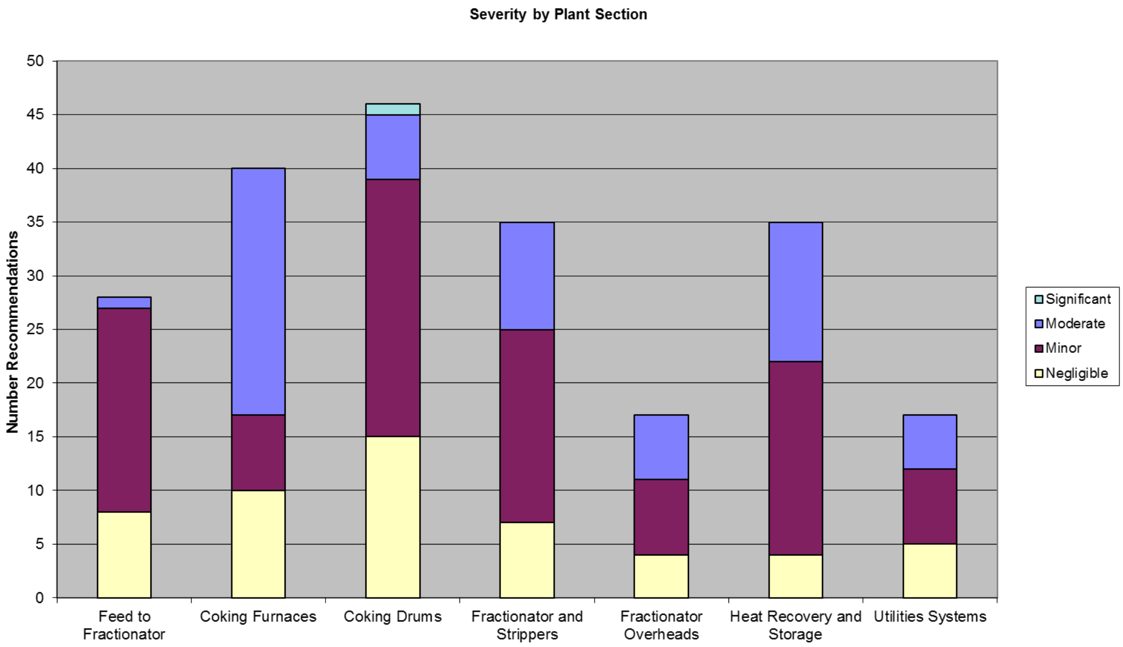
Causes	Consequences	Safeguards	Recommendations
3. Operator error opening drain valves on the drain line as well as valve on the utility line instead of opening valves on the condensate line.	1. Routing of hot hydrocarbon to atmosphere (coke pit). 2. Potential for fire.		R. Consider provision of permissive for drain valves to only be opened if valves on vapour line are in a closed position.
4. Operator error opening valves on condensate line when valve on utility line is in an opened position.	1. Potential to align coke drum to atmosphere via the drain line.	1. Permissive preventing opening of valves on condensate line unless valve on utility line is in closed position.	
5. Operator error opening valve on utility line when valves on condensate linear in an opened position.	1. Potential to align coke drum to atmosphere via the drain line.	1. Permissive preventing opening of valve on utility line unless valves on condensate line are in closed position (Logic I-XXX).	



The use of motorised valves (MOV's) allows valve position switches to be included in the logic controller responsible for a permissive to continue to the next step in the sequence. The justification for such a protection depends on the frequency in which drain errors occur. In one plant, we found 10 such errors occurred in the 20 years of operation for which records were available. These position switches are normally included in modern Delayed Coking Unit designs. Other instrumentation may be installed to contribute information as well adding another layer of protection i.e. pressure transmitters, etc.

Implementing HAZOP recommendations

Unless the recommendations from a HAZOP study or accident investigation are implemented the risks of a repeat incident remain. To expedite implementation, it is essential to approve the appropriate allocations needed to complete the recommendation. We believe that all HAZOP recommendations should be prioritized using the appropriate risk assessment tools available to the plant engineers. The risks can then be mitigated by implementing the proposed change to design or operational procedure.



The assessment of the risk can be based on the recorded losses which have occurred in those coker incidents which have been reported. Tables such as the one below give a snapshot of reported losses.

Pipe failure	COK	Baton Rouge Louisiana	2-Aug-93	72.4	$ M96	6" carbon steel elbow failed in region exposed to temperatures up to 480C. The design had specified 5% Cr alloy steel. Fire burned for 3 hours and destroyed two of the four drilling derricks. The affected coker was under repair for a year
Maintenance	COK	Equilon Anacortes Washington	24-Nov-98			Fire caused by release of vapour during opening of coking drum. Unit had shut down for power failure, had cooled and became plugged. 37 hours after power failure attempt was made to open drum after failure to clear plug with steam injection. . The top head was unbolted and lifted from the drum. The bottom head was also unbolted and held in place by a hydraulic dolly. The operator then activated a release mechanism to lower the dolly. Witnesses reported hearing a whooshing sound and seeing a white cloud of vapor emanate from the bottom of the drum. The hot petroleum vapor burst into flames. The process supervisor, an operator, and the four contract personnel assisting were caught in the fire and did not survive
Fire	DCOK	Killingholme UK	16-Apr-01	80	$01Million	Fire in a saturated gas plant. Under control in 2 hoursDamaged sat gas plant and coker heater. Two people were injured in an explosion at a refinery involving large amounts of LPG and petroleum. The blast occurred in the saturate gas unit. The closure for repairs will coincide with a maintenance turnaround already scheduled. Two people were injured, police officials said -- one was a plant worker who was treated for shock by Conoco, and a local resident hit by flying debris. Failure of the deethaniser overhead pipework due to corrosion erosion
	COK	Tosco Carson California	23-Apr-01			Flames and smoke billow from an uncontroled fire in a "coker" unit at the Tosco oil refinery Monday, April 23, 2001, in Carson, Calif. The fire burned for more than two hours, sending a huge, back, cloud of smoke floating eastward over Long Beach and surrounding communities.
Explosion	DCOK	Horizon Oil Sands Fort Mckay Alberta	6-Jan-11	600	$2011 million	Fire at top of one of four coke drums. fire resulted from opening the top unheading valve on an active low-pressure Coke Drum. This allowed the release of hot hydrocarbons within the coker cutting deck building, which was followed by ignition and the fire. Further investigation will determine if equipment malfunction or a break down in operating or maintenance practices occurred
	COK	Pasadena	10-Dec-11			A fire broke out Saturday night in the coking unit at Petrobras 100,000 barrel per day (bpd) Pasadena, Texas, refinery, the company said in a statement on Sunday. One worker received minor injuries and was transported to an area hospital. Pasadena Refining System Incorporated has contracted GSD Demolition (Houston, Texas) to demolish derricks and scaffolding on its 12,500-barrel-per-day (BBL/d) delayed coker. The delayed coker unit was damaged by a fire on the unit on December 10, 2011. Pasadena Refining is planning to replace antiquated coke drums that were built in 1969 and install bottom unheading devices on the coke drums. The demolition is expected to be completed by July 2012.

Tables such as this indicate the largest scale of losses which have occurred and a minimum frequency of these occurrences. We understand and expect that other incidents have occurred but are not publically reported or investigated. While past accident information of this kind may be useful for safety specialists to be effective it also needs to be converted into specific instructions applicable to the plant under review. We believe this can be achieved by writing Operations Safety Instructions.

Operations Safety Instructions

As well as recommendations made in the FEED and EPC HAZOP which once agreed upon can be implemented by the project contractors, it is also important to pass the understanding of potential hazards and the means to reduce their associated risks achieved within the HAZOP in a form suitable for future use by plant operators. Operations Safety Instructions convert the general principles of risk reduction controls into specific instructions, to be implemented by plant operators.

Specifically referring to the accidents we discussed it is clear that careful valve line-up is essential for the safe un-heading of the coke drum. In a plant where this has not been automated partial or full manual activities may be necessary.

(1) General precautionary principles

The un-heading procedure must eliminate the risk of exposure of the operators to the drum contents. This requires steps to reduce/eliminate the risks from either a hot spot or a hot tar ball existing in the coke drum prior to head removal. Operations staff must understand that abnormal situations such as feed interruptions or incomplete drum quenching may allow hot spots to reside in the drum. If the steam or quench water does not permeate the bed, isolated hot areas can remain within the coke and any residual water which finds these hot spots can cause a geyser of steam, hot water, coke and hydrocarbon from drum openings after the heads have been removed.

Therefore, operators need to identify and correctly interpret any operating anomalies during the coking cycle, or drum quenching which may allow a hot spot or tar ball to form. In the accidents described, this would include the example of a loss of power or any other reasons for unconverted residue to accumulate in the drum. A detailed operating procedure must be in place to eliminate incomplete drum quenching or worse, a tar drum to develop. In the event, unconverted residue is known to exist in the drum the module must be bypassed and the appropriate steps must be taken to ensure the drum can be handled safely. The drum cannot be un-headed until all risks have been evaluated and attended to. The first accident we discussed graphically illustrates the potential outcome if this risk evaluation is skipped in favour of a fast decision or one favouring operational convenience.

The drum contents cannot be exposed to oxygen until they are well below ignition temperatures. It may take days to cool the contents of the tar drum to a temperature low enough to allow the drum to be safely unheaded. These circumstances require a solid team approach by knowledgeable people (including Engineering, Mechanical, Operations and Maintenance) to avoid disasters such as we have discussed above.

Part of the protective measures will include restricted areas in which people are allowed to assemble. It may become necessary essential workers are required to access the structure during these steps but a managed plan should be in place to minimize the duration that these workers are exposed to known dangers. It can only be allowed in circumstances in which there are prepared escape routes for rapid evacuation. The injury toll in the first two accidents we discussed was high because such precautions were not taken.

Un-heading devices (Top and Bottom) provide added protection to the operator. Remote Local Control Panels should be installed to provide a safe location for the operator to unhead a coke drum or operate coke cutting equipment.

Interlock systems requiring a permissive to operate the unheading devices can eliminate the risk of the inadvertent opening of the unheading device (Top or Bottom) on the coking drum. Other physical protections such as cutting tool enclosures/blow-out preventors help create a safe environment for todays Delayed Coker Operator.

2) Specific precautionary steps

A correct valve sequence is essential to safe drum operation as the cycle steps progress and these should be the basis of the Operations Safety Instructions

- Midpoint Switch
- Steam to Fractionator
- Steam to Blowdown
- Quench and Fill
- Drain
- Unheading
- Decoking
- Reheading and Purging
- Pressure Testing
- Preheating (Backwarm)

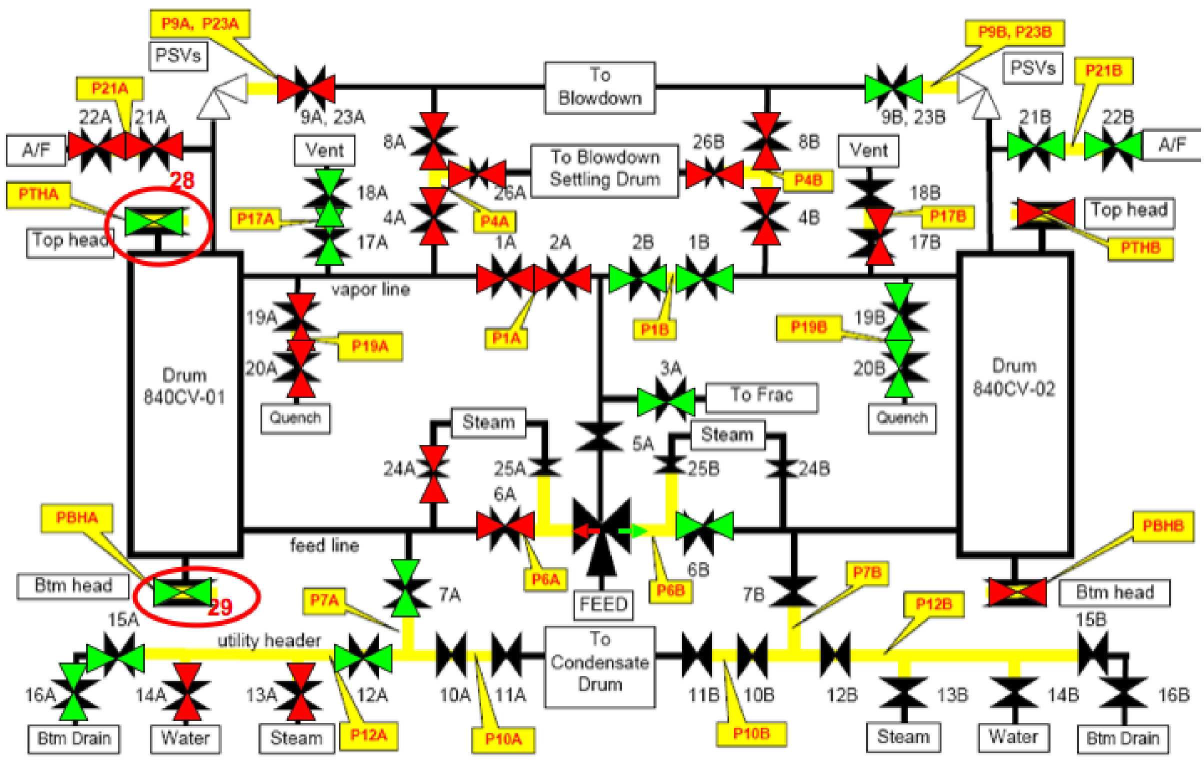
The training which rolls out the Operating Safety Instructions must communicate the fundamental process requirements which underlie this sequence so that operators can appreciate the reasons for each step in the sequence and the hazards which may arise if any step is compromised.

These steps can be implemented by using a manual sequence or by incorporating interlocks which have specific valve actuation which can be further understood by referencing summary diagrams. A simple mechanical approach is to use trapped key interlocks to ensure a correct valve sequence. A more advanced approach is to use programmed interlocks which for example:

- Prevents the field operator from accidentally opening any hydrocarbon source such as SP-4, SP-8, SP-1, SP-2, SP-6, XV-19/20 quench oil, XV-21/22 antifoam while the drum unheading devices, vent valves, drain valves are in the open position.
- The Coke Drum PSV isolation valves must be open to satisfy the permissive to close the drum vent valves.
- Before the top and bottom unheading devices can be operated the interlock ensures all hydrocarbon sources to the drum are isolated.
- The interlock prevents movement of the Top Unheading Device (TUD) if the drum pressure is above the set point of the drum pressure permissive. The same is true on temperature. If the temperature of the drum is above the set point of the drum temperature the Top Unheading Device (TUD) cannot be opened.
- The interlock also prevents the Bottom Unheading Device (BUD) to be operated prior to the (TUD) being moved to the wide open position and verified.
- The (TUD) is prevented from being operated until the (BUD) has been moved to the closed position and verified.
- As a further protection the interlock can prevent closing the top slide valve until the drill stem has met the out of drum permissive.

The Operating Safety Instructions are based on sequence diagrams to help operators link the general safety precautions to specific valve actions on the plant.

Step : Unheading (V01 in Decoking Mode, V02 in Coking Mode)



Such diagrams could have helped avoid the referenced accidents. For example investigation of one fire on the coker cutting deck showed the drum was open for coke cutting operations but the SP-1 and SP-2 valves were open, contrary to the schematic shown above. There were no lock out procedures for these valves yet it is well recognized that lockout/tagout procedures are an important protection for coke drums. Modern designs have included interlocks that would deny the permissive to open the unheading devices (TUD & BUD) if the vapour line valves (SP-1 and SP-2) were in the open position.

It is the job of the entire refinery team (community) to ensure that accidents described above are not repeated. Attention to detail and smart management practices can prevent these incidents for being repeated. It takes contributions from everyone involved to ensure these incidents are avoided.

Concluding Remarks

The lack of fundamental understanding of the refinery processes remains a continuing concern especially when this lack of knowledge affects participation in HAZOP meetings. When the team is comprised of very inexperienced engineers rather than knowledgeable operations people/engineers this may in itself become one of the root causes of the repeated incidents refiners experience in Delayed Coking Units. The HAZOP process offers the chance to continue to learn from shared experiences of unfortunate, dangerous and costly incidents. We must continue to communicate the lessons learned and not miss critical information needed to avoid a re-occurrence especially in Delayed Coking which is a very unforgiving process where many incidents have resulted in fatalities as well as life limiting injuries.

Much of the training of operators and maintenance workers is on the job training which is only as good as the top individual in the group. It can be that this type of training doesn't satisfy the requirements operators and maintenance workers need to successfully manage unusual or rarely encountered situations. In the worst case groups lack a basic understanding of the fundamentals required to safely perform the tasks they are responsible for and we see continued repeat incidents that could have been prevented with very little effort and many times a minimal financial investment.

Many factors may contribute to these repeated incidents but one cause arises when the engineering methods chosen to manage or eliminate risk actually adds to the complexity of the process. Complicated solutions increase the associated risks rather than eliminate them and are more likely when the right people to be involved in the decision, the experienced solid performers are too busy with higher priority projects.

Although the Delayed Coking Process has not changed that much over the years and remains an endothermic thermo-cracking process many operational facets have changed. The feed processed in the Delayed Coking Unit today is much different than it was twenty years ago. Delayed Coking cycles have been shortened from a normal 24 hour cycle to 12-14 hour cycles in an attempt to maintain throughputs required to process heavier crude slates. As the cycle time decreases it becomes apparent that the operator must be very good at each step of the coking process to ensure that the drums can be ready for the next cycle. Because Coking is a function of time and temperature, shorter cycles affect the total residence time of the material being coked and most Delayed Cokers are designed now for an 18 hr. cycle in the coking mode. The off-line coke drum is quenched, vented, unheaded, drained, decoked, steam purged and back warmed and placed back into hydrocarbon service over the same 18 hrs. Thus the true cycle of the drum is 36 hours, during which the operations team in the Delayed Coking Unit remains very busy. Operators must remain focused in what is a semi-batch process that does not run in a steady state condition.

The requirements for safe operation are:

- A clear understanding of the process fundamentals.
- Clear and concise operating procedures.
- Defined Interlock Schemes that are easily understood and Operator Friendly.
- Defined training programs that are updated as the process changes.
- The Process Safety Management Team must understand the unit operation and management must approve the requests for design improvements, training programs and see that the lessons learned are not overlooked.
- HAZOPS and Process Audits must be taken seriously if the refiner is to operate in a safe accident free environment. It is not always easy to do the right thing.
- Proper Alarm Management must reduce the total number of alarms sent to the DCS annunciator panel. Operators must be able to handle the total of alarms recorded.
- The control schemes should not be so complex that they are misunderstood.

When advanced control schemes are implemented the concern is that many operators have not learned which fundamental control points need to be maintained.

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