

NUMALIGARH REFINERY LIMITED

Note to: SGM (TS)

Date: 11.06.2015

Kindly find attached for your kind perusal, the enquiry committee report on the minor fire incidence that occurred in CDU/VDU plant on 02.05.2015. This is in line with your office note Ref. No. FINRL 105151600001 dtd 15/05/2015.



Pallav Kr Das

CM (TS)



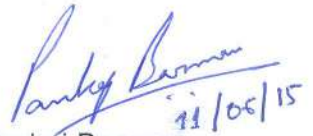
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NUMALIGARH REFINERY LIMITED

INVESTIGATION REPORT OF MINOR FIRE INCIDENT AT CDU/VDU

Date of Incident: 02.05.2015

Committee Members:

- | | | |
|----------------------------------|---|-----------------|
| 1. Pallav Kr Das, CM(TS) | - | Convener |
| 2. Manabendra Gogoi, M(M/M) | - | Member |
| 3. Pranjal Pathak, M(Inspection) | - | - do - |
| 4. Pankaj Barman, M(TS) | - | - do - |

Vide office note (Ref. No. FINRL 105151600001) dtd 15/05/2015, a committee has been constituted with the above members to investigate the incident that has happened at CDU/VDU unit at 11.12 PM on 02/05/2015 and to find out the immediate and basic causes of the incident and recommendation(s) thereof.

The committee members have investigated the incident and discussed with concerned personnel from field and Control Room. Findings of the committee are detailed below:

A. Description of the incident:

On 2nd May'2015, shortly after feed cut-in in CDU/VDU, at around 11.05 pm, field personnel present in the plant heard a huge sound and saw a stream of vapor coming out from the transfer line of VDU furnace to the Vacuum column. Subsequently, it was seen, a fire broke out on the same transfer line near the VDU furnace. Immediately, furnace was isolated by activating Emergency Shut-Down switch from CDU/VDU control panel of CCR. The fire was extinguished within 5 minutes with the help of fire tender & nearby fire monitors. However, there was a huge vapor cloud formation seen in that area, which gradually has subsided after 3-4 hrs. Fire water pouring was continued during entire period

The immediate cause of the fire was due to leakage of hot hydro-carbon liquid from a thermo-well branch pipe which got damaged due to vibration of the transfer line as well as probable explosion that took place inside the transfer line or the VDU column flash zone. Since the material leaking through the broken thermo-well branch pipe was above auto ignition temperature, immediately it caught fire.

B. Activities prior to the incident:

Before the incident, start-up activities in the unit were going on post RTA. After handover of the plant by maintenance, CDU & VDU circulation was established at 5.30 am on 02.05.2015 and furnace burner lit up at 7.20 am for hot circulation. CDU feed cut-in was done at around 10:30 PM and VDU feed cut-in was under progress. Thereafter, RCO was diverted to VDU column (CC-06) at 10.50 pm. Also vacuum pulling was started in CC-06 at 10.52 pm. Stripping steam to CC-06 was not introduced at that time, as the bottom liquid level was on a higher side. During this moment, just after VDU feed cut-in, at around 11.04 pm, field personnel present in the plant heard that huge sound as described above.

Following major activities were carried out as part of s/u activities in CDU/VDU plant:

(I) CDU Section:

SL No	ACTIVITIES	Date	Time
1	Line-up and checking of loops & charging utilities.	26.04.15	
2	Steaming of crude preheat train & CC-01.	27.04.15	5.00 AM
3	Leak checking of CC-01 and connected headers	28.04.15	
4	N2 back-up and pressure hold-up test at 1kg Press	29.04.15	
5	Taking crude into unit up to Desalter	30.04.15	8:30 AM
6	Taking crude up to Crude column and start cold Circulation	29.04.15	3:00 PM

7	Furnace(FF-01) lit-up and hot circulation in CDU section	30.04.15	6:30 PM
8	Flange leakage from furnace (FF-01) radiation coil outlet thermo-well	01.05.15	1:00 AM
9	Replacement of faulty thermo-well (15 nos) completed	02.05.15	5:00 AM
10	Lighting up of FF-01 and re-establishment of hot circulation in CDU section	02.5.15	5:30 AM
11	Hot bolting of pre-heat train exchangers, column flanges etc.	02.5.15	1:00 PM
12	Feed-cut-in to CDU	02.05.15	10:30 PM
13	Feed cut-out due to leakage of thermo-well & minor fire	02.05.15	11:08 PM

(II) VDU Section:

SL No	ACTIVITIES	Date	Time
1	Steaming of CC-06.	28.04.15	
2	FG back-up, leak test and pressure hold test	29.04.15	
3	Vacuum retention test at -0.4 Kg/cm ²	30.04.15	7:25 PM
4	S/U circulation in CC-06 with Gas oil	30.04.15	9:30 PM
5	Furnace radiation coil outlet thermo-well flange leakage	01.05.15	1:00 AM
6	Replacement of faulty thermo-well (15 nos) completed	02.05.15	5:00 AM
7	Lighting up of FF-02 and re-establishment of hot circulation in VDU section	02.05.15	7:20 AM
8	Heating of column, Hot bolting of flanges of VDU section	02.05.15	2:00 PM
9	Feed-cut-in to VDU	02.05.15	10:50 PM
10	Vacuum pulling through ejector	02.05.15	10:52 PM
11	Hearing of explosion sound & minor fire	02.05.15	11:04 PM
11	Feed cut- out due to leakage of thermo-well & minor fire	02.05.15	11:12 PM
12	Fire put-off at around	02.05.15	11:17 PM

C. Activities after the incident:

- Emergency shutdown of the unit was taken with immediate activation of 'Furnace Emergency Shutdown' switch from the control room hardware panel.
- Fire call was given to fire station over telephone as well as through VHF set.
- Fire tender along with fire crew and F&S S-i-C arrived at the incident site immediately.

- Prior to arrival of the fire tender, water spray had already been started by the operation crew at the site of fire through the high volume long range (HVLR) monitor located in the North of CDU/VDU.
- Immediately after arriving at the site, fire crews laid the fire water hose from the fire tender and started spraying water and foam through fire water hose also.
- Fire was completely doused within 5 minutes of firefighting.
- Spraying of water was continued through 2 nos. of High Volume Long Range monitors from both sides of the unit as a precautionary measure as well as to cool down the area for some more time.
- FD fans were run continuously to cool down the furnace during the fire fighting period.
- Velocity steam was charged into FF02 coil to displace the transfer line holdup towards column.

D. Major Observations:

Regarding personal injury, one officer got minor injury on his knee due to trip and fall on the floor area of the unit while initiating fire fighting arrangement. Few notable observations related to VDU Furnace outlet line (Transfer line) and VDU column (CC-06), due to suspected explosion (as huge explosion sound was heard) are as below.

- Crack at the thermo well (TI-2010) pipe of common transfer outlet line header (42") of VDU Furnace (FF-2) leading to leakage of hydro-carbon liquid.
- Bending of few numbers of PG/PT tapping of FF-2 coil outlet line.
- Displacement of FF-2 outlet line from its support.
- Displacement of pipe no 14"-P-01-2005-B1F-IH (FF-2 Pass-I o/l) from low support cross guide pedestal.
- Shifting of spring support and clamps out of position of pipe 14"-P-01-2006-B1F-IH (FF-2 Pass-II o/l). Pipe support hanger was also got broken off.
- Shifting of spring support and clamps out of position of pipe 14"-P-01-2007-B1F-IH (FF-2 Pass-III o/l), also support hanger got misaligned.
- 02 nos defect observed during DPT in TE 2014 bent and fillet weld above i/v, & PG 2010 of pipe 14"-P-01-2007-B1F-IH (FF-2 Pass-III o/l) got bent.

- One L-shaped hanging support got broken off from RCC beam (above Pass-II o/l header). Concrete got damaged at one location near Pass-II o/l header.
- FF-2 Pass-IV outlet to 42" header, 14" branch pipe fillet weld to RF pad ID crack observed at one location towards south side.
- FF-2 Pass-III outlet to 42" header, 14" branch pipe fillet weld to RF pad ID Crack found at two locations.
- VDU Column visual inspection was carried out from outside through few of the manholes opened after the incident and partial damages observed in Bed no # 6, 7 & 8 and their respective spray headers / distributors. Also below Flash Zone, partial damage observed on the Tray # 4 (Stripping Tray) from top.

E. Critical operating data prior to the incident:

Following are the few critical operating parameters just before the incident:

- The vacuum pulling rate was observed to be on higher side (-872 mmHg in 15 minutes from 10.49 pm to 11.04 pm).
- Rate of introducing ejector steam was on higher side (Steam flow reached from zero to 3000 Kg/hr within 05 minutes of introduction)
- At the time of incident there was sudden increase in flash zone pressure from -518 mmHg to +29 mmHg (at 11.04 pm within 30 seconds). Thereafter again vacuum was restored to -501 mmHg (at 11.06 pm).
- Level in CC-06 bottom was high and was more than 100 % since 22:23 hrs. Although it came down once to 99.9% at 22.58 hrs but it remained more than 100% during the incident period also.
- During the period the RCO flow to VDU Furnace, FF-02 COT and VR flow (ex CC-06 bottom) was found normal.
- Stripping steam was not introduced into the column CC-06.
- Drastic change on slop cut to VV-08 draw off temperature (CTI2107) was observed, which came down significantly to 107 °C from around 207 °C just before the incident took place. VV-08 bottom pump PA-21A/B was on stop condition at that time.

- Level of VV-8, though the indication was not so reliable, sudden change in level was observed during the slop cut draw off temperature change just before the incident. The level came down drastically to zero (0 % from 100 %).

F. Root cause analysis:

The committee members after initial discussion decided to adopt the following methodologies to find out the immediate and basic causes of the incident and recommendation(s) thereof:

- Site visit
- Interviews and discussions with individuals
- Log book / log sheets of operational areas
- DCS data analysis
- Team discussion & listing of probable causes

As said in "A: Description of the incident" above, the immediate cause of the fire was due to leakage of hot hydro-carbon from the damaged thermo-well (TE-2010) flange pipe. The 1^{1/2}" pipe got damaged due to the thrust in the 42" transfer line which transmitted in eastern direction towards furnace as a result, one support plate (stopper) of the transfer line broken and the 42" header got shifted momentarily and led to crack of the 1^{1/2}" pipe due to the impact with nearby concrete structure.

This effect of the 42" transfer line was due to the probable explosion that took place inside the transfer line or at the flash zone of VDU column. The location of said explosion can be ascertained from the fact that the trend of flash zone pressure of the VDU column (Refer Trend-1 in **ANNEXURE - I**) at the time of incident that shows sudden high pressure spike, which can only be caused by violent pressure charge from an explosion inside. During the incident period, steam flow to ejector system was steady and that shows no sudden vacuum break from the ejector side. The sudden positive pressure spike in flash zone (higher compared to column overhead), indicates location of explosion is near the column flash zone. Same is substantiated from the fact that sound was heard near the VDU column.

Probable cause of explosion:

(I) Air/water ingress from the slop distillate pot (VV-8):

Slop distillate pot (01-VV-008) remains in floating condition with the VDU column just above the flash zone during operation. The draw-off line from CT-1 comes to the upper part of the vessel and the vapor return line from the vessel top goes back to VDU column above CT-1. From bottom of the vessel, the line goes to VR + Slop recycle pump suction (01-PA-21A/B) and from the pump discharge, one part goes to VR rundown and the

second part goes back to VDU Furnace (FF-2) as recycle. The draw-off temperature indication (CTI-2107) is placed in the incoming line from VDU column just before entering the vessel.

It has been observed that initially the draw off temperature (CTI-2107) of VV-08 was increasing gradually with the increase in FF-2 COT and the subsequent increase in flash zone temperature. However, just before the time of the incident it came down significantly after starting of vacuum pulling (Refer Trend-2 in **ANNEXURE - I**), which indicates back flow of cold fluid (either air or condensate) through the line from VV-8 or from PA-21 A/B suction line. As vacuum pulling rate was high, sufficient cold fluid ingress into the hot system (inside VDU column) may have influenced the explosion. Here it is to be noted that PA-21A/B was not started on that day and the isolation valve in the minimum circulation flow line was found wheel free and the Low-point-drain nozzle in that line with $\frac{3}{4}$ " valve was found in closed position but not in blinded condition.

(II) Condensate carryover through the Stripping steam line:

The stripping steam to VDU column from the superheated header is generally introduced through a 12"X18" line with a flow control valve (12" FV-2110) having two isolation valves at u/s & d/s, one b/p globe valve, one block valve at d/s and finally one NRV just before entering the column below flash zone. The distance from the block valve at d/s of Control valve to the NRV as well as the column body is near about 5m (Five meter 18" line) approx. There are two low point drains with $\frac{3}{4}$ " isolation valves, one at the d/s of the Control valve and one just before the NRV.

Here, if the condensate in this line is not sufficiently drained through these two low point drains, there is a possibility of condensate trapped in the portion from d/s of the control valve to the u/s of the NRV. During initial hot circulation of the column, the system remains at positive pressure (about 0.5 Kg/cm²) and as a result the NRV flapper is at closed condition due to the back pressure from the column side when there is no sufficient steam flow. However with the starting of the vacuum pulling due to negative pressure created in the system may lead to open up of the NRV flapper allowing the trapped condensate to move to the column inside causing water shot / hammering effect due to sudden expansion of the low temperature condensate subjected to the high temperature exposure inside the column. It is to be noted that the low point drain at the upstream of the NRV was found choked and indicates that condensate draining through this LPD might not have been done before start up.

For the above two points, please refer the sketch for VV-08 & the Stripping steam injection to VDU column, attached as **ANNEXURE – II**.

(III) Air ingress through leaky flange:

The FF-02 COT was about 300 °C before the incident which is well above at auto ignition temperature; and the air ingress required for explosion, might have occurred through the leaking flanges while pulling the sudden high vacuum rate in the column after the feed cut-in of VDU section. One such likely possible air leakage source is the body flange (6") of CC-06 draw line (6"-P-01-2130-A6N-IT) to VV-08. It is to be noted here that during leak testing carried out on 07.04.2015 after the incident, minor leakage found from that particular flange. Therefore air ingress through this flange to column inside during vacuum pulling might take place to cause explosion.

(IV) High liquid level in VDU column:

In case of very high level in the vacuum column bottom and subsequent rise of level build up may cause damage inside. However, though the column bottom level was at 100% most of the times, but it was observed that level came down to 99% at 20.58 pm to 11.03 pm (Refer Trend-3 in **ANNEXURE - I**), which indicates that liquid hold up at column bottom was not high enough to build any flow disturbance through the transfer line. Also no other indication of flooding at flash zone was found as well as the stripping steam was not introduced into the column during the time.

(V) Water carryover in VDU column with feed:

Water or condensate carryover along with VDU feed in the transfer line can cause violent hammering while heating. But no hammering was observed during hot circulation and prior to feed in. Moreover, velocity steam was not introduced till then and as such possibility of sudden condensate carryover through the furnace to transfer line could not take place. Also probable accumulated water in VDU column IR/CR & product loops were drained out during VDU column pressurization period before circulation of VDU Column.

G. Recommendations:

After thorough study of the whole incident as well as the analysis of the probable causes, following are recommended:

(I) Special attention should be given on the following pre-start up activities after any major or minor maintenance jobs during shutdown in any of the segment or areas of vacuum section.

- Leak testing using ribbon & soap solution and pressure hold up test @ 25mm Hg drop max per hour to be logged.
- Vacuum retention test value to be logged.
- Draining of condensate through all LPDs of stripping steam header and all connecting loops of CC-6 including VV-08 and its associated piping to be counter checked by Shift-in-Charge.

(II) After the pre-start up job, while moving forward with the plant start up activities like cold or hot circulation, if it is to be aborted to carry out any maintenance job again in between in the vacuum section, then the activities mentioned in the point no (I) above are to be repeated for ensuring safe start up of the unit.

(III) As such, s/u circulation & feed cut-in procedure and steps as shown in **ANNEXURE- III** should be available in hard copy in the control panel before each start up.

(IV) To avoid fast vacuum pulling, procedure for vacuum pulling in vacuum column should be followed as per the procedure given earlier via mail sent by CM(Ops) dtd. 05.05.15 (Enclosed as **ANNEXURE - IV**). All activities should be logged separately and signed by the SIC.

(V) One modification is to be done with proper MOC for providing steam trap & b/p valve (Drip-leg assembly) at the existing low point drains at Striping steam line to vacuum column (at CV d/s and at u/s of the NRV).

(VI) The repairing of the damaged 11/2" thermo-well nozzle was carried out by grounding off from the half coupling and then inserting plug in the half coupling. Finally the plug was fillet welded with half coupling to seal the plug with the half coupling. However, in the next opportunity the respective thermocouple is to be made functional again with removal of the plug and the necessary modification.

(VII) Necessary inspection is to be carried out in the next planned shutdown for the entire transfer line and subsequent rectification including the balanced support related job in the pipe rack.

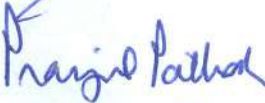
(VIII) Vacuum column was inspected from outside through the opened manholes. The partial damage of column internals observed during inspection has been noted down carefully for rectification/replacement in next opportunity. As such, this rectification/replacement job may be planned in next planned shutdown and action may be initiated for procurement of the required materials ie column internals by the concerned group accordingly. Detail Inspection of VDU column internals should also be carried out to find out any abnormality from operation and safety point of view.

Report prepared & submitted by:

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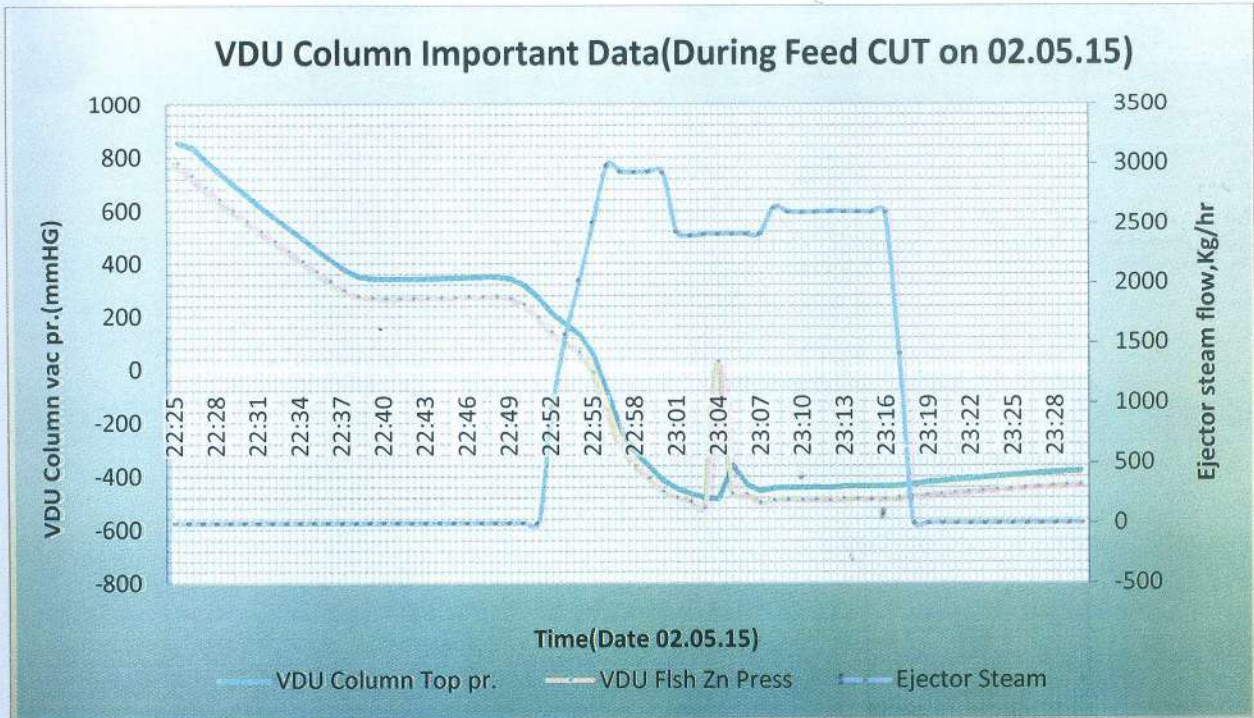


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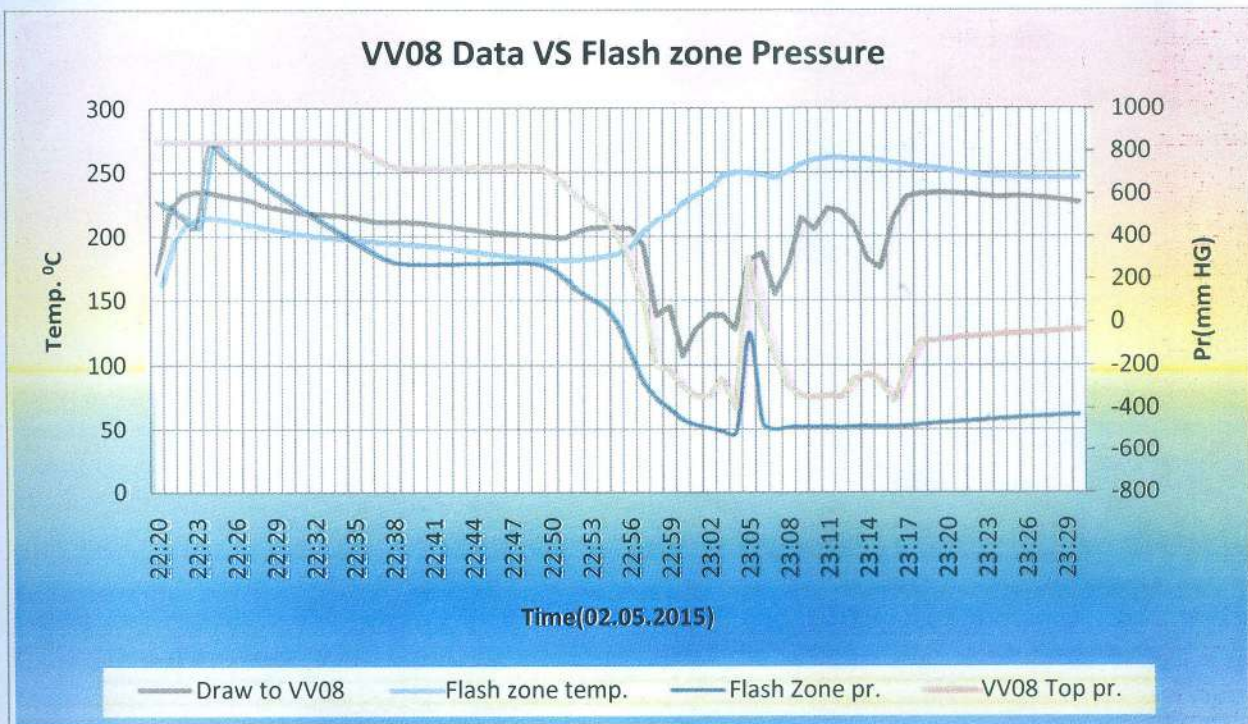
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Column Flash Zone Pressure Trend-1

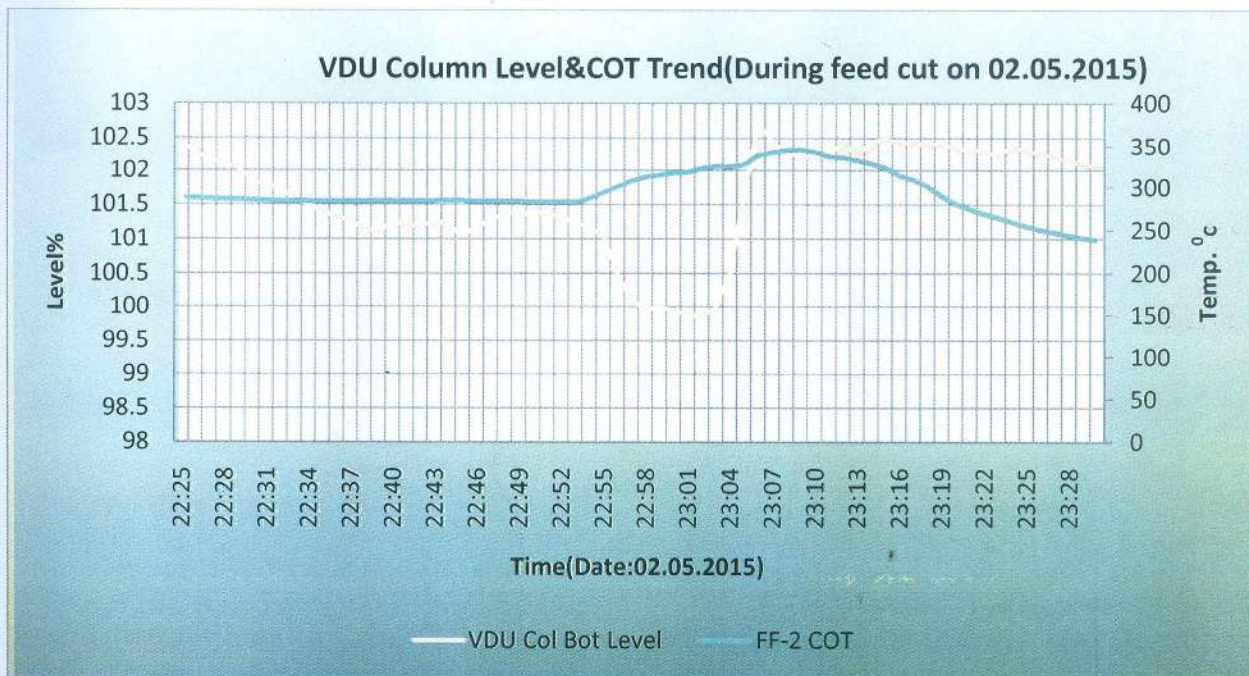


VV-8 draw Temperature & Flash Zone temperature, Trend-2

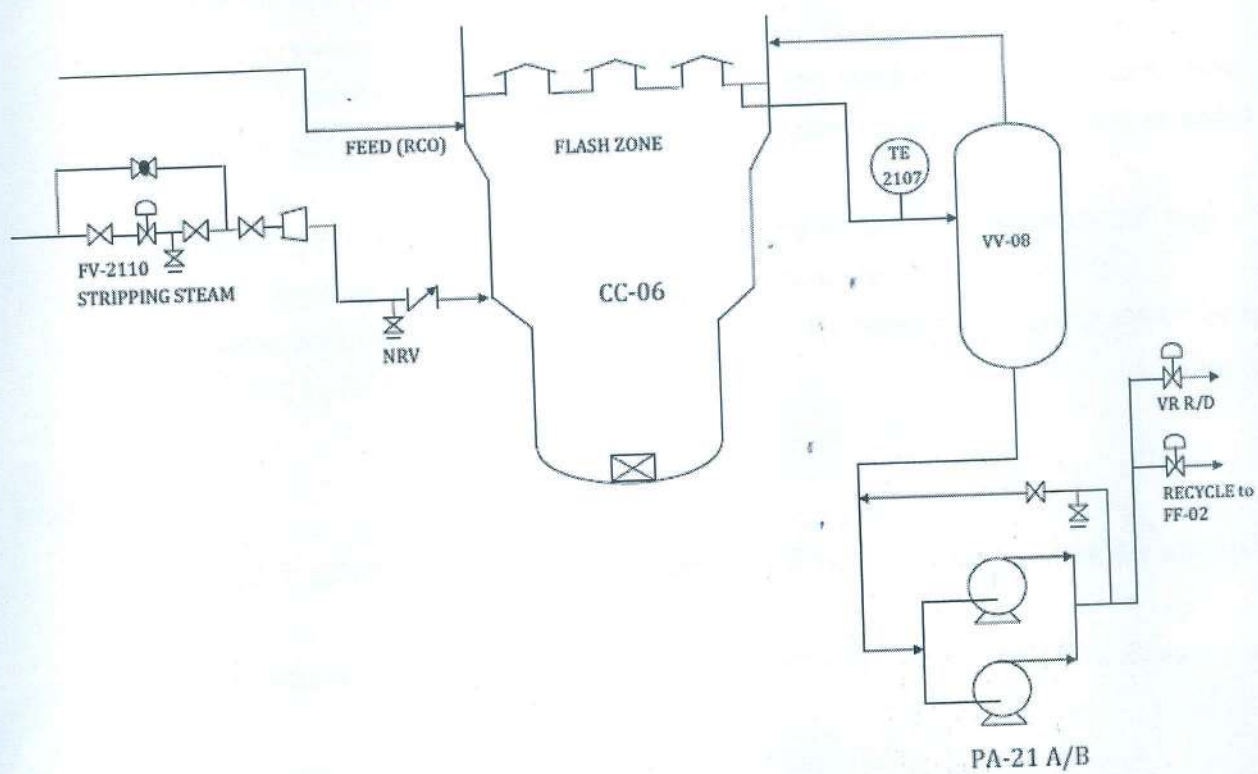


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contd.

Column bottom Level and Flash Zone Temperature, Trend-3



P-2/2

SCHEMATIC DIAGRAM: VDU COLUMN BOTTOM

PRECAUTIONS / MONITORING TO BE DONE FOR SMOOTH START UP OF CDU/VDU

CDU SECTION:

- Keep crude oil flow rate through heater at about 50-60% normal throughput
- The rate of increase of transfer line temperature will be restricted to 30 deg C/hour
- When the COT reaches 120 deg C, hold & maintain this temperature for four to six hour
- Raise COT to 250 deg C @ of 30 deg C/hr & maintain column bottom level at about 50%
- Start hot bolting in hot service where normal operating temperature exceeds 200 deg C
- Prepare the stripping steam header by draining condensate from drain points
- Once column bottom temperature reaches 300 deg C, introduce stripping steam step by step @ 250 kg/hr in each step

VDU SECTION:

- Increase COT to 120 deg C @ 30 deg C/hr rate & hold the temperature for about 4 hours
- Raise the vacuum furnace COT to 220 deg C at the rate of 30 deg C/hr & start hot bolting
- Divert RCO from RCO pump discharge to vacuum furnace
- During circulation, column bottom level should be maintained as low as possible
- Raise COT to 300 deg C @ of 30 deg C/hr
- Once RCO is diverted to vacuum heater and pumps are stabilized, commission ejectors and pull vacuum slowly
- Introduce stripping steam step by step @ 250kg/hr & closely monitor the column bottom level
- Raise the COT to normal value of 398 deg C
- Slowly commission 2" velocity steam lines to FF-002 radiation zone coils
- It is to be ensured that the interlock for stripping steam cut at VDU column bottom level high high, CLHH-2110 is in line during start-up as well as in normal running of the plant.

The following points are to be ensured for smooth operation with structured packing in order to avoid uplift or disturbances in structured packing

- Ensure condensate free steam as stripping steam to column
- Ensuring steady heat input to column
- Ensuring steady vacuum pulling operations
- Ensuring stepwise increment in CR/IR flow rates
- Ensuring correctness of bottom level of main column to avoid bottom liquid level to increase beyond stripping steam nozzle
- Avoiding any major water shot from Desalter to main column

PROCEDURE FOR VACUUM PULLING IN VACUUM COLUMN:

- Commission cooling water to all ejector condensers 01-EE-54 A&B/55/56.
- Ensure normal level in hot well, seal compartments are filled with water and the water seal is maintained. Ensure that all dip legs in hot well are sealed in water.
- Isolate the valves on vacuum column product pump suction, vent lines of each pump connected with vacuum column, hot well overflow seal line and hot well vent to furnace to achieve perfect sealing of vacuum system from atmospheric section.
- Water in hot well seal overflow should be filled.
- Commission MP steam to ejectors. There are 2 set of ejectors (primary& secondary). The capacity of ejectors of each set are as mentioned below:
 - **Primary ejectors(JA-01 A/B/C)**
 - i. JA-01A: 1/7
 - ii. JA-01B: 2/7
 - iii. JA-02C: 4/7
 - **Secondary ejectors(JA-02A/B)**
 - i. JA-02A: 1/3
 - ii. JA-02B: 2/3
- Slowly start pulling vacuum in the vacuum column taking JA-02A of the second stage ejectors in line.
- After establishing a vacuum of about **-50 mmHG**, take the primary ejector JA-01A in line and increase the vacuum further.
- Vacuum pulling should be done slowly. PC-2301 should be used for controlling the vacuum pulling rate. Also control the MP steam flow to ejectors.
- To improve vacuum further take one more secondary ejector JA-02B.
- Air/Vapor in the column will be gradually sucked out from the system including transfer line (downstream of Vacuum Furnace pass flow control valves), vacuum column and all product/ CR draw off lines. It is to be noted that hot well shall not be under vacuum.

- Watch pressure in the system. Gradually lower the pressure to the maximum (approx - 0.8 Kg/cm² by increasing MP steam flow.
- When there is no further lowering of pressure block off the system and hold under such conditions and check for vacuum holding. Isolate the ejector inlet and outlets. Shut off steam. Isolate PV-2301. Initially there may be rapid drop during the process of blocking off.
- If the rate of fall of vacuum does not exceed **0.05Kg/cm²g per hour (approximately 40 mm Hg per hour)** the system is assumed fairly tight.
- In case vacuum retention test is not ok. Leak checking has to be carried out by pressuring the system to above 1 kg/cm²g with air and applying soap solution on every joint. If pressuring testing is carried out rigorously, the vacuum testing is expected to be satisfactory for vacuum column and its connecting piping and equipment.