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Failure of Kettle Type Condenser in Steam Condensate Service – A Case Study

Mayank Banjare
Indian Oil Corporation Limited, Panipat Refinery & Petrochemical Complex, Panipat, Haryana, India
banjaremayank@indianoil.in

B. K. Muduli, Rahul Prashant, L. C. Gopalani
Indian Oil Corporation Limited, Panipat Refinery & Petrochemical Complex, Panipat, Haryana, India

ABSTRACT

Kettle type condensers are the most troublesome condenser type in the chemical process industries. Several criteria and rules of thumb for kettle type exchanger operations are used, most popular of which is keeping the top row tube surface not less than 55 % of the shell diameter. Despite the significant demand placed on the condenser and exacting penalties for condenser leaks, the condenser often does not get the attention it deserves.

In the subject case the high boiler column of linear low density polyethelene (LLDPE) handles the tail gases from the low boiling column, which is composed primarily cyclo-hexane and separates the cyclo-hexane from the grease and high boiling impurities. The high boiling column overhead vapor is fully condensed in kettle type condensers that generate LP steam for distribution. Leakages in the tubes of these condensers cause cyclo-hexane slippage to the steam condensate system causing loss of cyclo-hexane and creating a hazardous environment in the steam system. This paper describes the methodology adopted to identify the root cause of tube failure in kettle type condensers, including remedial measures and precautions to avoid failure of such condensers.

Keywords: Nucleate Boiling; Acid Corrosion; Cavitation; Kettle type Condensers / Phase Change Heat Exchangers

INTRODUCTION

Tube leakage was suspected in the HB condenser E-216B. Subsequently the condenser was opened for testing by dropping the channel box, but the tube bundle was not pulled out. A total of 61 tubes were observed to be leaking and were plugged by seal welding. Thereafter a hydro test was carried out on both the shell and tube side and was found to be satisfactory. However, after putting the condenser in operation leakage again was suspected. The problem was twofold, (i) loss of cyclo-hexane from regular consumption pattern and (ii) cyclo-hexane ingress in the condensate circuit. Hence, the condenser was opened during the planned shutdown in August 2016 for external inspection of the tubes.

Table 1: History of HB Condenser

S. No.	Date	Description
1	May 2010	HB condenser (E-216B) was commissioned.
2	June 2014	Shell flange to tube-sheet gasket was observed to be leaking during operation. Steam leak from the shell flange was sealed on-line by installing ring-clamps and application of sealing compound.
3	April 2016	Exchanger was opened for the first time since commissioning of the unit because of suspected tube leakage. Total 61 tubes were found to be leaking and the same were plugged and seal welded.
4	July 2016	Exchanger was opened for the second time since commissioning of the unit because of suspected tube leakage. 33 new tubes were found to be leaking and the same were plugged and seal welded.
5	April 2017	Tube bundle replaced with new one.

PROCESS DESCRIPTION

The HB column (C-202) takes the tails from the LB column (C-201), which is composed primarily of SH (cyclo-hexane), and it separates SH from grease and high boiling impurities. The HB column receives two feeds. The main feed is the LB column bottoms and the second feed is the overheads product of the RB column (C-203). The HB column overhead vapour is fully condensed in kettle condensers (E-216A/B) that generates LP steam for distribution. From the reflux drum (V-203) the solvent is then sent forward to reaction or refluxed back to the column (C-201). The base flow is sent for further removal of grease and heavy impurities from the solvent in the RB column (C-203). Schematic sketch is shown in figure 1.

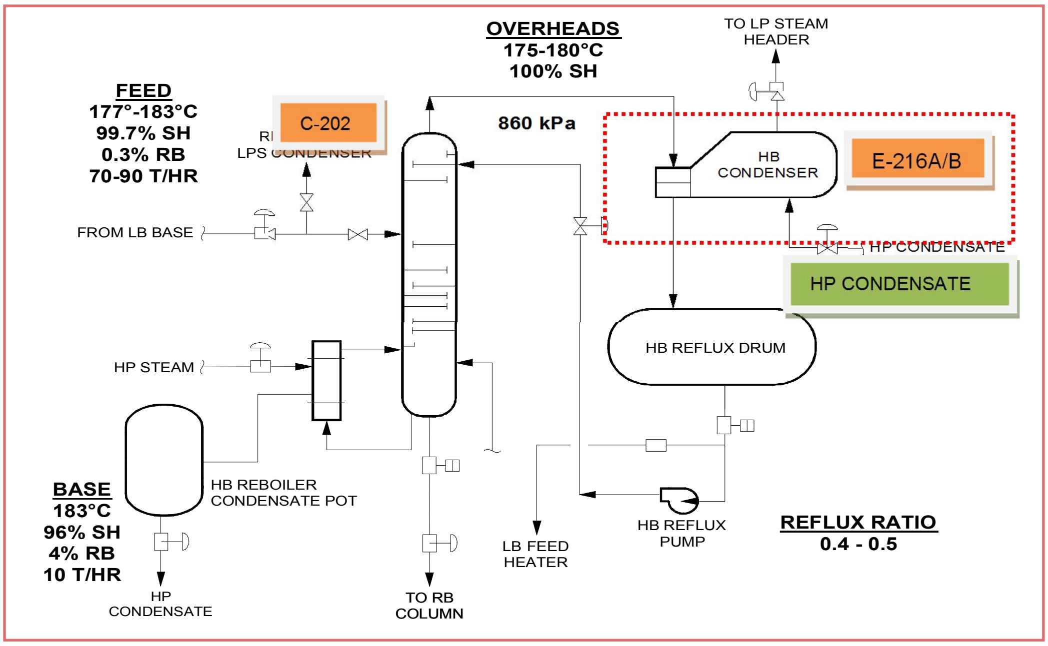


Figure 1: Schematic Sketch of HB Column and HB Condenser

Table 2: Design Specification of HB Condenser

Description	Shell Side	Tube Side
Design Code	ASME Section VIII DIV.1 ED 2004 ADD 2006, TEMA Class 'R' 1999 Edition + IBR	
Operating fluid	Condensate / MP Steam	Hydrocarbon
Working pressure	11.0 kg/cm2	9.3 kg/cm2
Design pressure	11.0 kg/cm2 / F. V	11.0 kg/cm2 / F. V
Hydrotest pressure	16.5 kg/cm2	16.5 kg/cm2
Working temperature	107 °C / 159.1 °C	180.5 °C / 172.5 °C
Design temperature	250 °C	250 °C
Corrosion allowance	3 mm	3 mm
Radiography	Full	Spot
Joint Efficiency	1.0	0.85
M.O.C	SA-516Gr70	SA179, U' Tubes 937 Nos. 20x2.3x6000

OBSERVATIONS

This is a horizontal kettle type exchanger with a removable U-tube bundle. After the tube bundle was pulled out followed by hydro jet cleaning, external pitting / grooving marks were observed on the tubes preferentially adjacent to baffle plate locations (please refer figure 2). External fouling with proprietary online gasket sealing material was observed on the tube surfaces. Grooving was observed in the peripheral tubes at the mid-level near baffle plate locations. Grooving was also observed on the tube external surfaces in the inner tubes. Deposits were observed on the shell internal surface at 6 O' clock location. Similar observations of E-216A was also observed but of lesser extent as per available level trend this condenser has been operated with higher condensate level. A plugged tube was cut and removed and split opened. No internal corrosion was observed. Other 8 tubes were cut to access this plugged tube. Condition of demister pad was found satisfactory. Ultrasonic thickness gauging was carried out on process side inlet / outlet piping to condenser and reflux drum V-203 outlet line bends. No significant thickness loss observed. Visual inspection with the help of Remote Visual Inspection tool after sample tube cutting was carried out. Grooving on tube external surface was observed preferentially at adjacent to baffle plate locations. Ultrasonic thickness gauging of the connected nozzles / shell body and channel box was carried out and no significant thickness loss was observed.

Figure 2: Photographs showing external grooving of the external surface of tube of the HB Condenser

JOBS CARRIED OUT

Continuous blow down (CBD) and intermittent blow down (IBD) pipes of the condenser were dechoked using nitrogen and fire water. Blackish deposits were removed during water flushing. Ultrasonic thickness measurement of the CBD and IBD lines were carried out and found satisfactory. For collecting a sample of leaky tube, total 8 tubes were cut in E216B. After cutting of tubes, grooving on tube external surface was observed preferentially adjacent to the baffle plate locations. The cut tubes (8) were plugged at the tube sheet end and seal welded. Total plugs= 102. Shell side of the condenser was hydro tested at 16.5 kg/ cm2 g.. Tube test and final test of the condenser was carried out at 16.5 kg/cm2 g and found satisfactory. Tube bundle was replaced with a new one in April 2017.

PROBABLE CAUSES OF FAILURE

- Acid corrosion on tube ID side.
- Low condensate level operation.
- LP condensate two phase flow impingement on tube bundle bottom portion.
- Un-symmetrical process flow on Tube side
- Material failure / Fabrication defect
- Under deposit corrosion

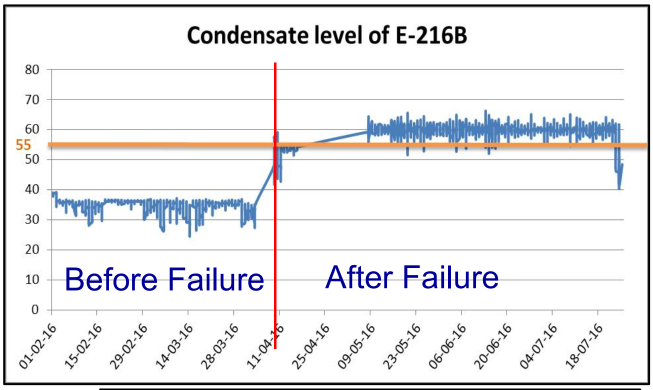
ANALYSIS

Laboratory Analysis:
Cyclo-hexane sampling is done regularly from the cyclo-hexane purifier (up-stream of the condenser), and does not indicate acidic impurities in cyclo-hexane. Laboratory analysis of the cyclo-hexane sample taken from the purifier outlet indicated chloride content as low as 3 - 5 ppm. Condensate analysis showed: Total pH-8.7, chloride-0.3 ppm, Iron-0.37 ppm.

Site Verification:
A site visit was made to ascertain equal flow distribution on process side piping. It was observed that the piping layout is symmetrical on the tube side for both the condensers and there is no control valve from column C-202 top to HB condensers E-216A/B inlet. However a flow difference of 1-2 TPH was claimed by the operation group in both the condensers. Symmetrical piping layout was observed across the shell side 4" LP steam condensate inlet piping distribution in E-216A/B.

Mass Balance Review:
Mass balance was studied for the process side fluid in E-216B. No acidic impurities was observed present in the cyclo-hexane from the HB column top to the HB condensers.

Trend Analysis:
Trends were analyzed for condensate level in condensers 31-E-216A/B as per distributed control system data available for period of 01.02.2016 onwards. A level of 30-35% was being maintained in E-216B and 35-40% in E-216A.



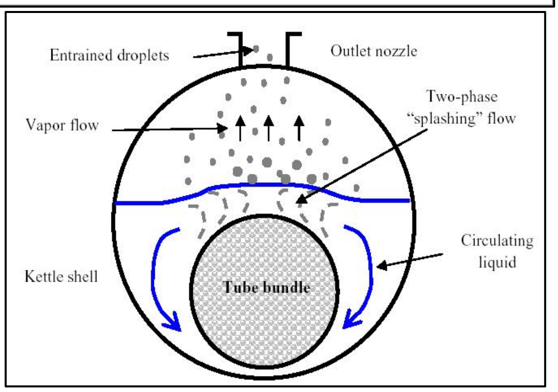


Figure 3: Showing Condensate level of HB Condenser before and after failure

DISCUSSION

Based on the study and physical findings the following probable causes of failures were analyzed with the help of a fishbone diagram (Figure 4) to pin point the cause of failure:

(A) Acid corrosion on tube ID side

The possibility of failure due to acid corrosion is ruled out as very low ppm (6-8 ppm) of acid was observed in cyclo-hexane sample analysis from the SH purifiers. Moreover no significant process piping thickness loss was observed in E-216A/B and reflux drum V-203 connected process piping. Licensor mass balance of stream does not show presence of any acid content. No tube edge thinning or pitting observed on ID side. The possibility of failure due to acid corrosion is ruled out as no internal corrosion was detected inside the tubes.

(B) LP condensate Two phase flow impingement on tube bundle bottom portion.

No impingement plate was present in the as built drawing. However, process datasheet indicates presence of an impingement plate at the condensate inlet face in the condenser E-216B. It was feared that in the absence of an impingement plate, and with two phase flow and high delta P across LV, erosion of tubes would have taken place. However, after the bundle was pulled and inspected, no erosion of tubes were observed at the inlet nozzle area. Hence, this probability of failure was ruled out.

(C) Un-symmetrical process flow on Tube side

Physical layout of piping layout was observed to be symmetrical in both the condensers 31-E-216A/B. Hence, this probability of failure is ruled out.

(D) Low Condensate level in E-216B

Per calculations made on the basis of LT length and tube-sheet ID, a level of 54.5% is required for complete tube bundle immersion. The condensate level trend was not monitored since commissioning of the unit and condensate level trend was analyzed only after leakage of the tube bundle. Past data of only last three months can be retrieved from the digital control system. The condensate level trend observed in E-216B is in the range of 35-40% as per distributed control system data. After bundle pull-out and inspection, grooving on the tube external surface was observed confirming that the leakage of tubes was due to nucleation boiling at the liquid level interface.

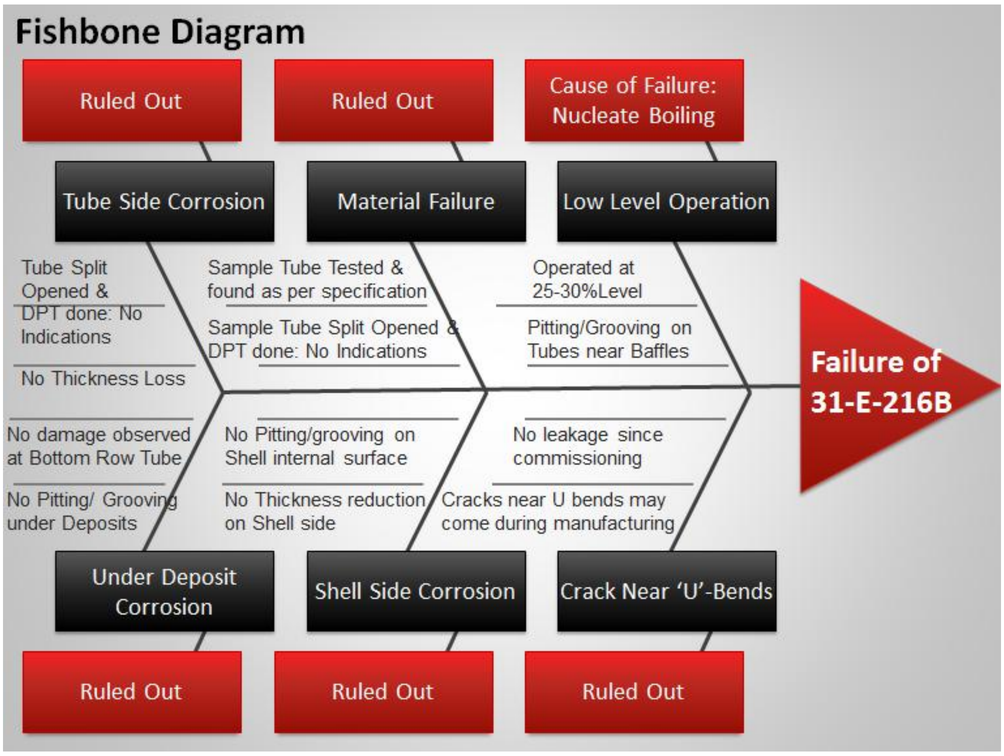


Figure 4: Showing Fishbone Analysis of HB Condenser Tube Failure

CONCLUSIONS

Grooving / Cavitation on the tube external surface confirmed tube leakages due to low flow operation which caused nucleation boiling on tubes external surface at level interface location preferentially at baffle plates locations.

To avoid such failure in future it was suggested to maintain minimum 55% condensate level in the condenser. Proper functioning of LT has to be ensured.

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REFERENCES

1. M &I department, Feb 2003, Indian Oil Corporation Limited “Corrosion Manual”
2. M &I department, Feb 2004, Indian Oil Corporation Limited “Heat Exchanger Manual”
3. API RP 571, Dec 2003, “Damage Mechanisms Affecting Fixed equipment in the Refining Industry”.