ET10: การวิเคราะห์สภาวะการผลิตของหอกลั่นสารอะโรเมติกส์ ด้วยเทคนิคการส่งผ่านรังสีแกมมา

ธนรรจน์ แสงจันทร์[1] อำไพ สุขบำเพิง[1] พิเชษฐ์ ลังบุปผา[1] ไพฑูรย์ รอดทองคำ[1] *สิริพล เชื้ออินต๊ะ[1]
ถาวร เกดสุวรรณ[2] รัชกิจ วิรัชกุล[2] กาน ภวภูตานนท์[2]
[1]สถาบันเทคโนโลยีนิวเคลียร์แห่งชาติ ถนนวิภาวดีรังสิต ลาดยาว จตุจักร กรุงเทพฯ 10900
โทรศัพท์ 0 2 579 8252 โทรสาร 02 579 0220 E-Mail: siripone@tint.or.th
[2]บริษัท ปตท อะโรเมติกส์และการกลั่น จำกัด มหาชน
เลขที่ 4 ถนนไอ-สอง นิคมอุตสาหกรรมมาบตาพุด อำเภอเมือง จังหวัดระยอง 21150
โทรศัพท์ 0 38-918000 ext 2072 Fax: 038-91-8152, E-Mail: thaworn.k@ pttar.com

บทคัดย่อ

ระหว่างปีพ.ศ. 2550-2552 ได้ทำการตรวจวิเคราะห์สภาวะการผลิตหอกลั่นสารอะโรเมติกส์ ของ บริษัท ปตท อะโรเมติกส์และการกลั่น จำกัด มหาชนในขณะที่โรงงานกำลังดำเนินการผลิตอยู่ตามปกติจำนวน 34 หอกลั่น โดยติดตั้งต้นกำเนิดรังสีแกมมา โคบอลท์-60 ขนาด 50mCi ไว้ข้างนอกหอกลั่นฯและติดตั้งหัววัดรังสีแกมมาในตำแหน่งตรงกันข้ามแล้วบังคับให้หัววัดและต้นกำเนิดรังสีเคลื่อนไปตามความสูงของหอกลั่นพร้อมๆกันพร้อมกับบันทึกข้อมูลความเข้มของรังสีแกมมาที่ทะลุผ่านหอกลั่นฯออกมายังหัววัดรังสีตามระยะความสูงต่างๆ แล้วนำมาเปรียบเทียบกับแบบโครงสร้างทางวิศวกรรม การตรวจสอบสามารถวิเคราะห์ได้โดยทันทีว่าหอกลั่นฯที่กำลังดำเนินการผลิตอยู่นั้นมีสภาวะการผลิตเช่นไร และ/หรือ มีชิ้นส่วนโครงสร้างภายในหลุดเสียหายหรือไม่ ช่วยให้โรงงานสามารถจัดเตรียมแผนงานการผลิต และซ่อมบำรุงได้อย่างมีประสิทธิภาพยิ่งขึ้น

คำสำคัญ: การตรวจวิเคราะห์หอกลั่น เทคนิคการส่งผ่านรังสีแกมมา การใช้ประโยชน์ในอุตสาหกรรม

GAMMA TRANSMISSION TECHNIQUE TO INVESTIGATE THE AROMATICS DISTILLATION PROCESSES.

Dhanaj Saengchantr[1], Pichet Lungbupha[1], Paitool Rodthongkam[1],
Umpai Sukbumperng[1], *Siripone Chueinta[1]
Thaworn Kedsuwan[2], Rachkit Virachkul[2], Kan Pawaputanont[2]
[1]Thailand Institute of Nuclear Technology (TINT)
Vibhavadee-Rangsit Rd. Ladyaow, Chatuchak Bangkok 10900
Phone: 02 579 8252, Fax: 02 579 0220, E-Mail: siripone@tint.or.th
[2] PTT Aromatics and Refining Public Company Limited (PTTAR)
4, I-2 Road, Map Ta Phut Industrial Estate, Map Ta Phut, Muang , Rayong 21150,
Phone: 038-91-8000 ext 2072, Fax: 038-91-8152, E-Mail: thaworn.k@pttar.com

In the technical Cooperation between PTTAR and TINT during 2007-2009, problem shooting process investigation of the 34 Aromatics production units, mainly distillation columns, was conducted by gamma transmission technique during plant on-line production. In common practice, a collimated 50mCi Cobalt-60 gamma radiation source and a collimated NaI (Tl) scintillation detector were set at the same horizontally alignment, opposite and along side the vessel and were then simultaneously vertically moved to several selected elevations. Transmitted gamma intensity penetrating through the vessel at each elevation was recorded and was plotted against the elevation. In comparison with engineering drawing of the vessel, status of process behavior and/or physical abnormality of internals such as foaming, flooding, blockage, damaged etc. could be indentified. This nuclear technology has been recognized as one of the powerful tools for management and planning of production and preventive maintenance program.

Keywords: Gamma Scanning, Gamma Transmission, industrial application.

1. Introduction

The on-stream gamma-ray transmission scanning technique is based on the measurement of the transmitted gamma intensity which is generated from the gamma source located at one side of the column to the gamma detector located at the opposite side of the column, while moving both source and detector along side of column from low elevation to high elevation or such versa. The original gamma intensity generated form the source (I_0) will be absorbed by the internal feature and media resulting lower transmitted gamma intensity (I) as followed by the equation:

$$I=I_0e^{\mu\rho_x}$$

Where μ= absorption coefficient, ρ=density of the column, x= column diameter or distance from source to detector. In case that the column diameter and wall thickness are constant, changing of the transmitted gamma intensity is directly related to changing of the internal feature and phase-density of the media, e.g. tray, distributor, liquid, froth and vapor etc. Thus, by comparing the transmitted gamma intensity and elevation profile with the engineering drawing, the physical status of the internal features and processing conditions occurring inside the column could possibly be evaluated for any abnormality e.g. tray damaged, mal-liquid distribution, flooding, foaming, weeping etc.

2. Equipments

1. Radiation Source (Co-60 or Cs-137)
2. Rate Meter LUDLUM Model 2200
3. Personal Computer and software

3. Methodology

3.1 Setting Radiation Source - Detector Orientations for Tray Column

In order to distinguish well defined tray with other abnormalities e.g. flooding, foaming, weeping etc, the orientation of gamma source and detector should be set avoiding the tray down comer, as shown in figure 1:

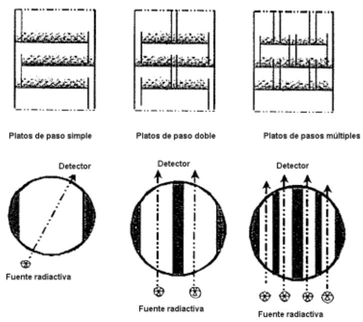


Fig 1. Internal structure of tray column

3.2 Scanning of packed-bed columns:

In general, length, blocking or fouling of the packing could be detected by normal gamma scanning. However, to inspect of the correct installation of distributors as well as the correct distribution of incoming liquid feed, the symmetrical grid scanning shown in figure 2 should be applied,

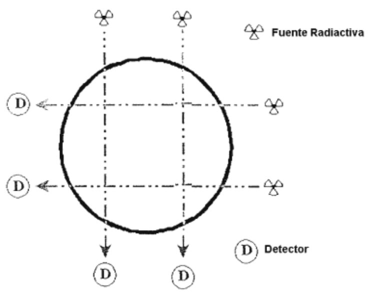


Figure 2: Scanning orientation of packing column

3.3 Data Interpretation

Gamma scanning profile provides a clear picture of the column internals, giving the internal structure, defects and column process state without interrupting the process. Basic data interpretation is described as the following:

- When the radiation beam crosses a liquid zone the weakest transmitted gamma intensity is obtained.
- When the radiation beam crosses a tray which is normally filled up with froth, most of the intensity is absorbed and a narrow peak is recorded. Negative peak means lowest intensity corresponding to the froth or liquid base line.
- When the radiation beam crosses a vapor zone, the intensity is the maximum (vapor base line), but the peak width is larger as a matter of fact that the vapor zone is larger comparing to liquid zone or tray size.

3.4 Typical process abnormalities

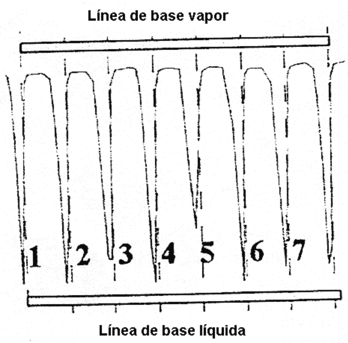
3.4.1 Obstruction/Flooding: Obstruction with flooding occurs on distillation trays when excessive liquid or obstruction causes accumulation of liquid on the trays. When these phenomena occur the liquid cannot go down the column.

3.4.2 Entrainment (Dragging): the hydraulic capacity of the trays is limited by two phenomena: excessive vaporization of liquids and over loading of the liquid. Entrainment is manifested by a zone of liquid carried over by the vapors resulting in small space for the vapor.

3.4.3 Emulsification (foaming): liquid on trays is agitated resulting in the escape of liquid into the vapor form producing different kinds of emulsions.

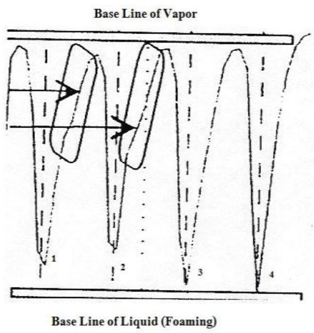
3.4.4 Weeping: The liquid goes down the space between two trays, the inverse phenomenon of vaporization.

3.5 Examples: Gamma Scanning Profiles of tray column. (Scanning Upward)



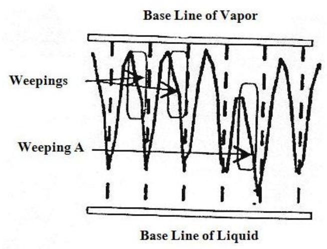
1 – Scanning profile of a normally operating distillation column

Scanning line is perfect and does not cross the jet channels. Between the trays, the intensity is the same as of vapor line. No anomaly is shown besides the tray 5 which is not identical with the other trays. This difference is not significant to identify an anomaly which could stop the column. This difference in intensity can be caused by external obstacles. The liquid level is almost the same in each tray.



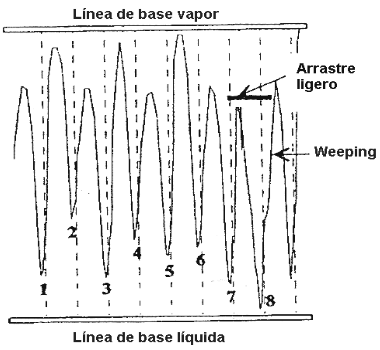
2 – *Gamma scanning of a column sector with foaming.*

A slight foaming appears on the two identical trays of the scan profile. The slope change appears just above the tray. There is no liquid entrainment or obstructions because there is no deviation from the vapor base line.



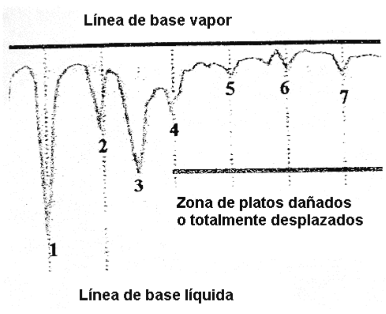
3 – *Gamma profile of a column part. With "weeping" (shower):*

Weeping is difficult to identify. An additional scan profile performed with week energy source is necessary to observe these phenomena better. The slope changes from the upper tray to next bottom tray. Two slight foaming areas are shown on two trays. Weeping is more evident in the tray A and may be caused due to the flooding of the tray.



4 – *Scanning profile through the down comers:*

The detected radiation intensity is lower under even trays (2, 4, 6) than under the odd trays. The scan of even trays partially crosses the down comers and the signals are absorbed more. A bad separation liquid/vapor is observed between the trays 7 and 8. This means that slight liquid entrainment from tray 8 to tray 7. The liquid level on the tray 8 is higher. Liquid weeping is visible at the tray 8.



5 – *Normal, displaced and missing and trays*

Tray 1 is intact and holds liquid.

Tray 2 holds relative small amount of liquid and is partially damaged.

Tray 3 is intact but slight flooding is observed.

Tray 4 is partially damaged. Trays 5, 6 and 7 are totally damaged and are displaced.

Typical intensity-elevation profile of normal operating column is shown in figure 3.

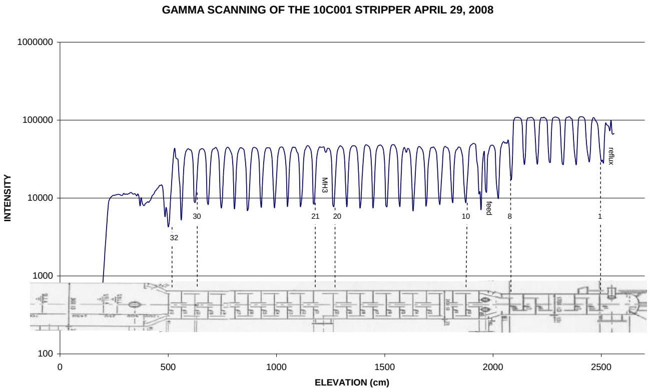


Figure 3: An example scanning result of normal operating column

3.5 Scanning Operation

Technical Cooperation between PTTAR and TINT during 2007-2009, problem shooting process investigation of the 34 Aromatics production units, mainly distillation columns, were conducted by gamma transmission technique during plant on-line production. Devices comprised a 50mCi collimated Co-60 radioactive source and a scintillation detector connected to rate meter and PC logging program. The source and detector were aligned at the appropriate orientation and elevation. Both devices were simultaneously moved up at each 5-10cms interval by using the hand winch system. Transmitted gamma intensity from the source after passing through the column at each position was logged by the Measurement Data Oil Refinery Technique (M-DORT) Software and plotted against the scanning distance by Excels. Interpretation was made by comparing the gamma intensity-scanning distance profiles with engineering drawings.

4. Results and Discussion

During 2007-2009, totally 72 process vessels of 5 petroleum refineries and petrochemical plants were inspected by gamma transmission technique (see figure 1). There were 34 cases Studies of Aromatics distillation of process vessels of PTTAR as described in table 1 in which 22 vessels were found normal while 17 vessels had some operational and physical problems such as less liquid retention on tray, foaming, flooding, and tray damage. Some vessels of high potential problems were selected for regularly investigation. For example, the 100-V3 Naphtha Splitter, the vessel was firstly inspected in November 2000 and it was observed from the relative gamma intensity-distance profile presented in figure 2 that most trays in top section (tray 1 to tray 24) were damaged. Tray debris fell on lower trays causing blockage and liquid flooding accumulating from tray 33 through liquid distributor to tray 24. Tray 34 to tray 50 had good definition with liquid loading and clear vapor spacing. Slight regular reducing of vapor count rates below even tray was normal as the scan line slightly intersected down-comers of those even trays. High absorption peaks at tray 50, 46, 42, 38, and 34 was due to effect of external rings only. The vessel was immediately shutdown for maintenance and trays damage/collapsed was visually confirmed as shown in figure 3. As the problems was identified in advance the shutdown for maintenance could be shorten thus saving huge economical losses. During plant debottlenecking program in 2006, the 100-V3 was modified with special designed trays in the lower section. The odd and even trays have 90º rotated down comers as shown in figure 4. Right after modification, the vessel was inspected and flooding in the lower section was observed in January 2007(figure 5). Routine inspection of this vessel was carried out as the annual basis for process optimization and the last result obtained in February 2009 represented the normal operating/optimized column. It was clearly observed that regular pattern of gamma intensity when passing and not passing each adjacent even-odd tray down comer. (figure 6).

The 433-V4 Toluene Column was constructed under the debottlenecking project and first base line inspected in June 2004. The tower showed good performance of well defined trays with froth loading and clear vapor separation between each adjacent tray as shown in figure 7. In June 2008 the tower experienced partial damage of trays 45-60 in the lower section in which the trays could not hold sufficient amount of froth/liquid as shown in figure 8. Up on visual inspection during maintenance shutdown in November 2008, those trays collapsed down to the bottom of the tower when there was more upward pressure from the gas stream. Pictures of the damaged trays are presented in figure 9.

The 2200-V7 Debutanizer comprises in the upper section, the special design trays namely "Advanced Dispersion Valve Tray (ADV tray)" with bubbling promoter to create very fine and homogeneous dispersed froth across the tray (figure 9). Very low froth/liquid loading on trays similar to partial damaged in the upper section was observed in the first inspection in November 2008 as shown in figure 10. It was doubted that the froth on tray might be too fine and too light to be absorbed by the high energy gamma ray of Co-60, so that the tray definition was not clearly indentified. In the next inspection in April 2009, low energy gamma source from 50mCi Cs-137 was used and better results of well defined trays in the entire column was observed as shown in figure 11. Conclusion could be made that the low energy gamma source of Cs-137 was more suitable for this special designed tray than the high gamma source of Co-60.

5. Conclusion

Gamma transmission technique was applied to investigate the physical status and process performance of the Aromatics distillation vessels during on-line production. Among 34 vessels investigated during 2008-2009, few vessels had physical and or process anomalies such as foaming, flooding, and damaged. Comparison between low energy gamma and high energy gamma was also performed for the special designed trays with very fine froth. It has been recognized that the technique was very useful to obtain sufficient information for better management and planning of production and preventive maintenance program in the Aromatic production Plants.

TABLE 1 DETAILS OF SCANNING OPERATION AT PTTAR AND INTERPRETATION

(Refers to engineering drawings and gamma intensity-scanning distance profiles of each inspected vessel)

DATE	VESSELS	No	Remarks
22-24 Jan 07	100-V3, 100-V5, 100-V7	3	100-V3 Flooding tray 25-57. Trays 1-24 light foaming. 100-V5 flooding trays 53-58. 100-V7 flooding trays 4-5.
15-17 May 07	100-V3, 100-V5, 100-V7	3	100-V3 Trays 1-24 light foaming. 100-V5 and 100-V7 normal
9-12 July 07	540-V5, 540-V8, 430-V1, 390-V3	4	390-V3 light foaming lower section, tray1 partial damaged. 430-V1 High loading lower section.
10-14 Mar 08	390-V3, 320-V5, 432-V1	3	320-V5 foaming upper section, 390-V3 foaming lower section, 432-V1 normal
8 -13 Apr 08	432-V7, 320-V7, 500-V4	3	320-V7 foaming upper section, 432-V7 flooding lower section, 500V4 normal.
12-13 May 08	433-V4	1	Trays 47-60 light loading, trays 1-15 almost flooding.
2-5 June 08	200-V7, 433-V4	2	200-V7 normal, 433-V4 trays 45-60 partial damaged
16-Oct-08	100-V7	1	Flooding around liquid distributor, dried trays in the top section
24-28 Nov 08	2100-V7, 2150-V4 2200-V7, 2380-V3, 2300-V5, 2540-V4	6	2200-V7 trays in upper section very dried, 2150-V4 trays 2-5 foaming, flooding from tray 1 to top reflux.
8-12 Dec 08	2320-V4, 2440-V3, 2500-V6, 2540-V7, 2540-V13	5	2540-V13 light foaming in top section
12-13 Feb 09	100-V3	1	Normal
7-9 Apr 09	2100-V5, 2200-V7	2	Normal
	Total	34	16 columns (47%) experienced process & physical problems.

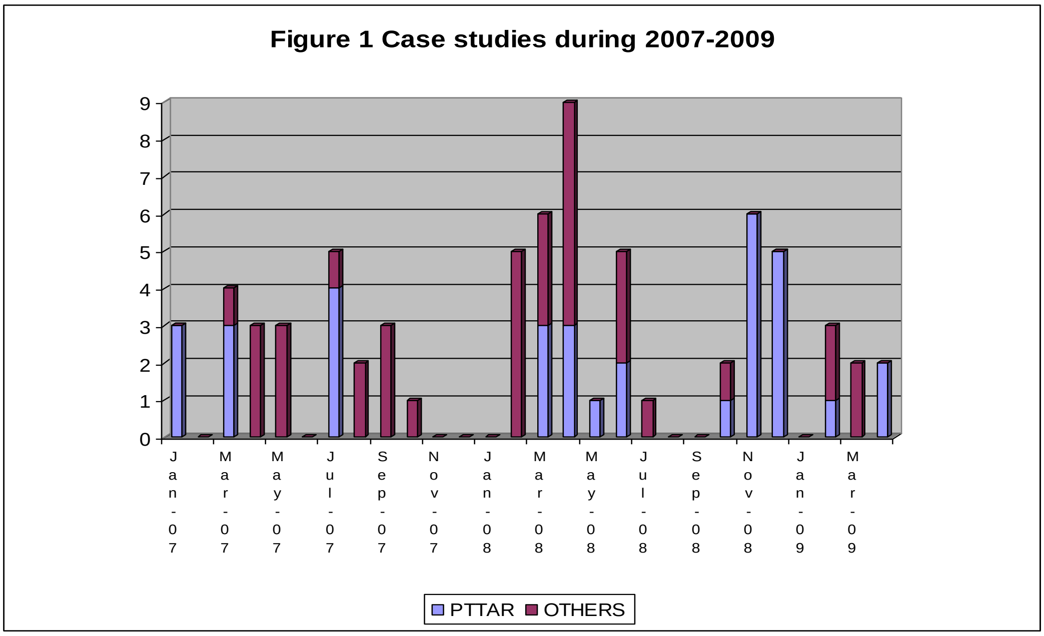


Figure 1 Gamma Scanning Records in the Petroleum & Petrochemical Industries during 2007-2009

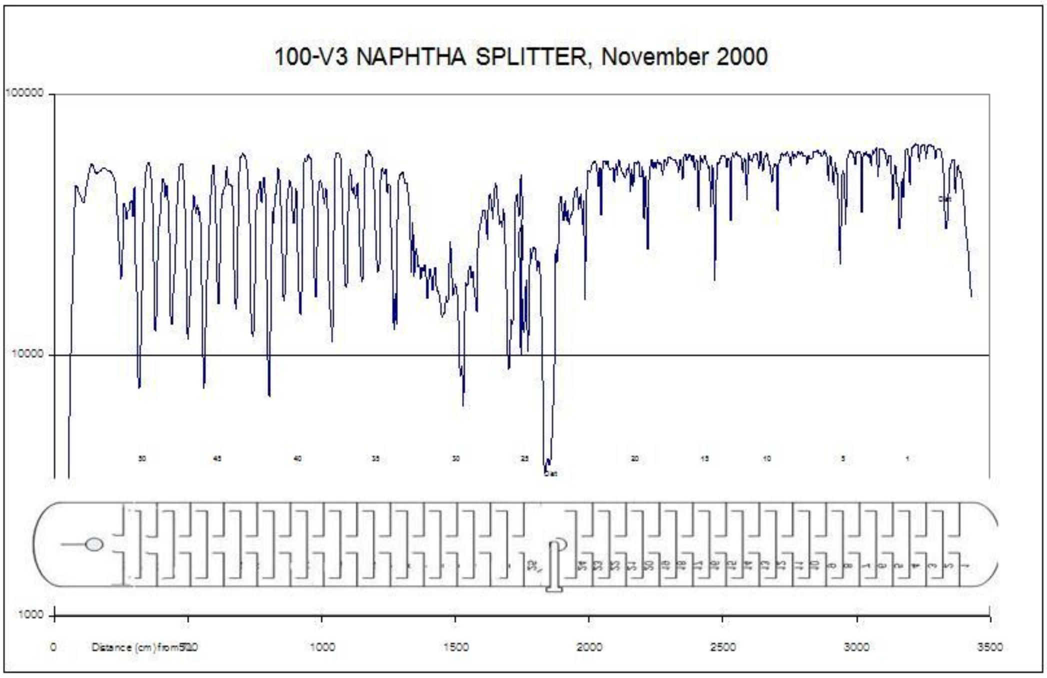


Figure 2 Tray damaged & Collapsed in the upper section of 100-V3 (November 2000)

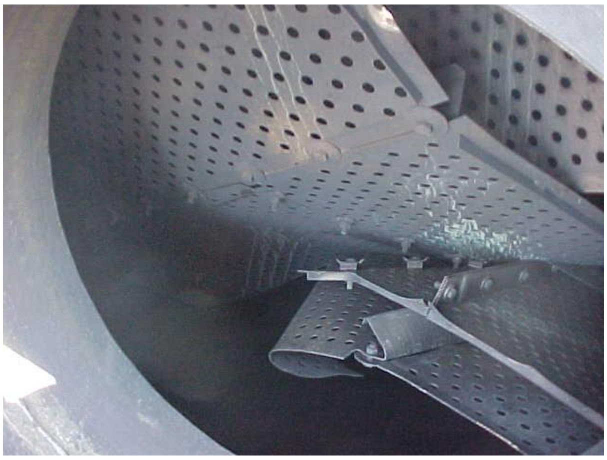


Figure 3 Tray damaged and collapsed from upper section to middle section of 100-V3 (Nov. 2000)

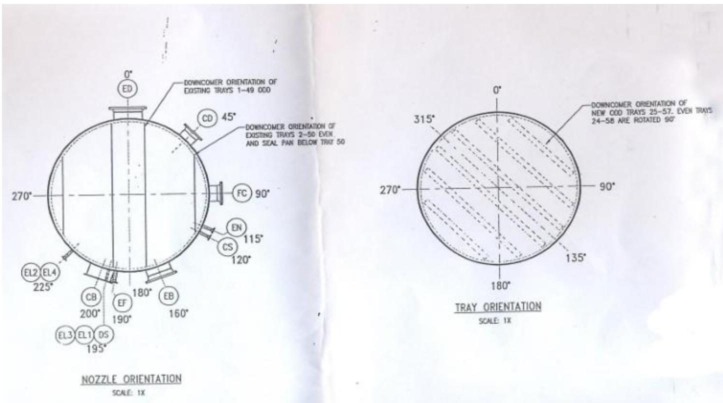


Figure 4 Special designed trays in the lower section of the 100-V3 Naphtha Splitter in 2006

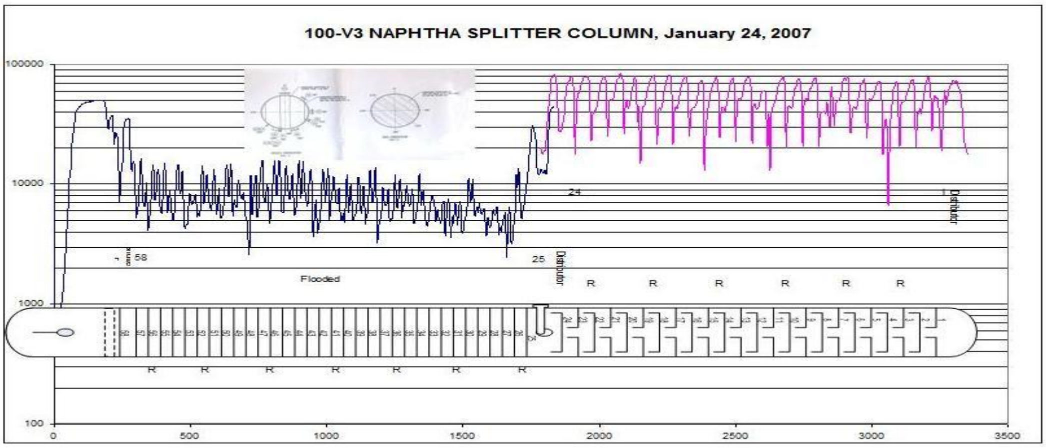


Figure 5 Flooding in the lower section of 100-V3 Naphtha Splitter observed in January 2007

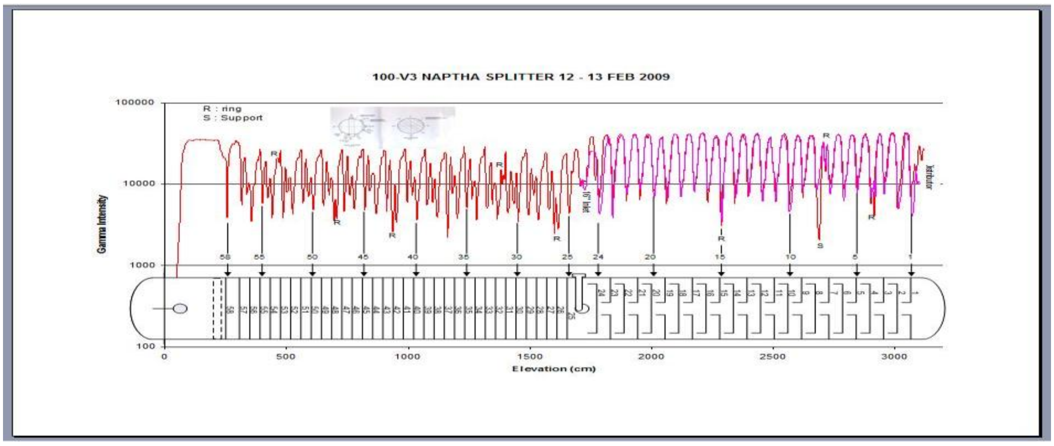


Figure 6 Normal operating & Optimized process of the 100-V3 Column observed in February 2009.

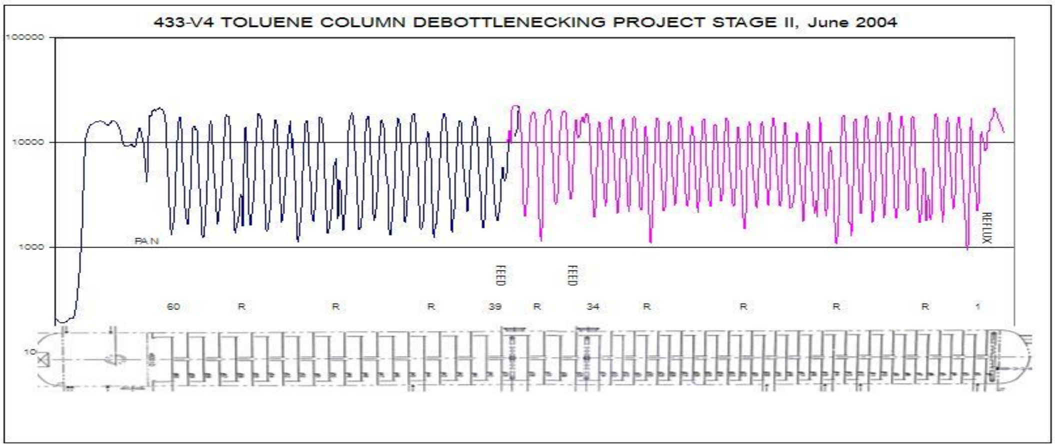


Figure 7 Well performance of the 433-V4 Toluene Column observed in June 2004.

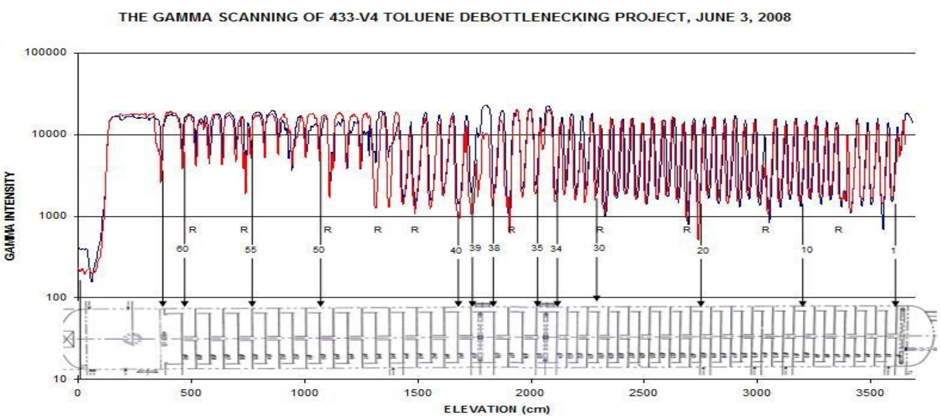


Figure 8 Partial trays damaged at the lower section of the 433-V4 Toluene Column in June 2008.

Figure 9 Damaged trays of the 433-V4 Toluene Column

Figure 10 Advanced Dispersion Valve Tray with bubbling promoter

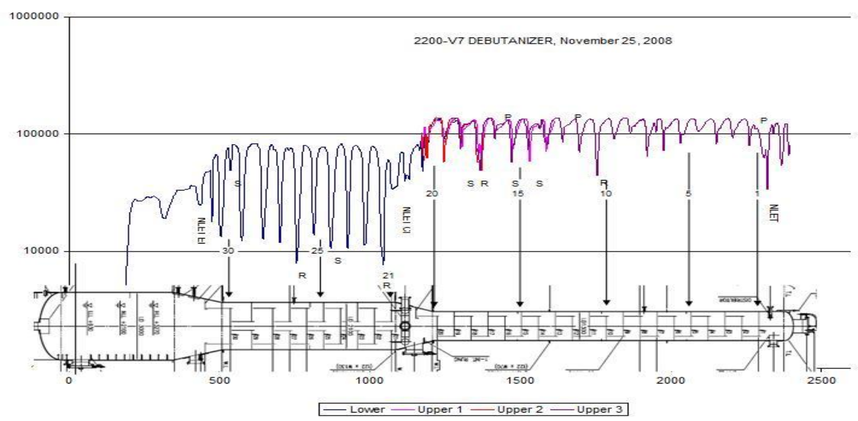


Figure 11 Scanning of ADV trays of 2200-V7 Debutanizer by Co-60 high energy gamma

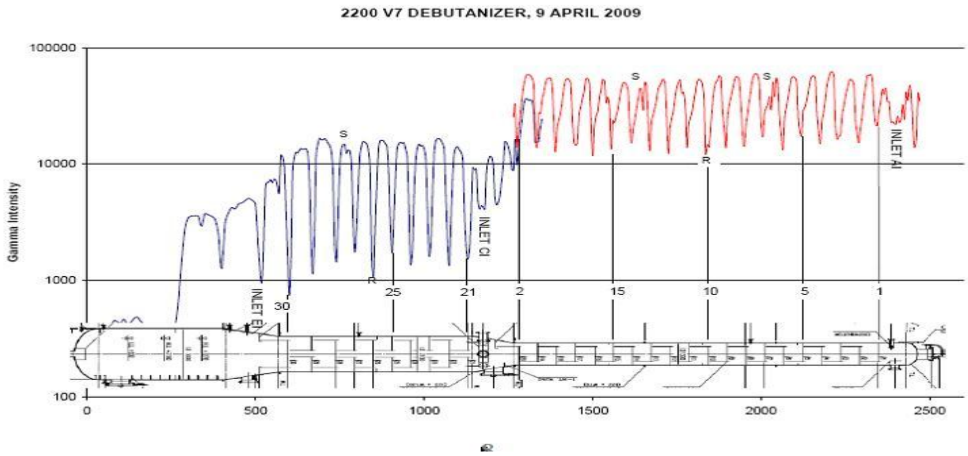


Figure 12 Scanning of ADV trays of 2200-V7 Debutanizer by Cs137 low energy gamma