Gamma Transmission Technique to Inspect Trays Condition of Distillation Column: An Experiment at Refinery Plant

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Abstract. In the petroleum refining process, distillation columns, operating under high-pressure and high-temperature conditions, are vital components responsible for producing crucial hydrocarbons. Conventional non-destructive tests often necessitate prolonged plant shutdowns, prompting the adoption of gamma column scanning, a nuclear-based, non-invasive technique with advantages in terms of speed, online troubleshooting, and safety. This study aims to detect suspected problems at the distillation column on trays #28 - #38., addressing the diversity of tray configurations and potential external obstacles. The scanning was performed using gamma radiation source 60Co with an activity of 1.74 GBq and a scintillation detector. Due to the tray configuration, the scanning was divided into two segments, which are top scans and bottom scans. The top scans were aimed to inspect trays #28 - #32, whereas the bottom scans were aimed to inspect trays #33 - #38. The scan lines were carefully selected to accommodate the investigation on all trays and also adapted to external column conditions that became obstacles to the probes (source and detector). The findings confirm the integrity of most trays but reveal suspected partial damage in trays #34 and #37, leading to flooding on tray #38, along with anomalies potentially caused by water or unknown materials. This research provides valuable insights into distillation column condition assessment and tray performance within the petroleum refining industry.

Keywords: Distillation, gamma scanning, hydrocarbon, petroleum, trayed column.

1   INTRODUCTION

Petroleum refinery plants play a crucial role in transforming raw materials (crude oil) into intermediate and final products, employing various processing units such as distillation columns, fractionation columns, heat exchangers, reboilers, and absorbers [1][2][3]. Among these, the distillation column stands out as one of the most vital

components, typically operated under continuous high-pressure and high-temperature conditions [2][4][5][6]. Its products have boiling points ranging between 70 - 200°C, encompassing valuable hydrocarbons like gasoline, naptha (used as a chemical feedstock), kerosene, jet fuel, and paraffin. The malfunction of distillation columns can lead to significant production losses, making their efficient operation essential for companies [3].

While engineers frequently rely on conventional non-destructive tests (NDT), such as radiography, magnetic particle testing, dry penetrant testing, ultrasonic testing, and eddy current testing for routine inspections during the fabrication, construction, service, and maintenance of process plants [7], these techniques often necessitate plant shutdowns (offline) for several weeks on average [3]. In response to this challenge, gamma column scanning has emerged as a promising nuclear-based technology offering advantages such as faster examination, non-invasive testing, online troubleshooting, cost-effectiveness, and enhanced safety [1][8][9][10]. To our best knowledge, there is little information regarding gamma column scan research, especially in the industrial field. This technique utilizes a gamma radiation source, typically ranging from 0.37 to 14.80 GBq (1,000 – 10,000 times lower than conventional radiography) and a radiation detector. The principle of the gamma column scanning method is placing the radiation gamma source on the side of the column and the detector on the other side horizontally at the same level of elevation [11][12][13]. The intensity of the transmitted beam is related to the path length and density of the material through which the beam passes when a gamma ray passes through a column. The tray position is shown in plots of radiation intensity or material density. A detailed analysis of these data enables making assessments about the condition of internal structures and process materials within the column.

In the context of this study, the focus is on gamma scanning of a specific distillation column to assess the condition of trays #28 - #38. There is a distillation column suspected of having problems at trays #28 - #38. The column is 45.9 m in height and 8.9 m in diameter. The trays have varying configurations, with tray #28 being a four-pass tray and trays #29 - #32 being two-pass trays, while trays #33 - #38 consist of donuts on odd trays and discs on even trays. Due to the tray configuration, the scans are divided into three segments: scans A, B, and C aimed at trays #28 - #32, and scans D – K aimed at trays #33 - #38. This research aims to provide a comprehensive understanding of the gamma column scanning technique's application in assessing the condition of trays in a distillation column and its potential benefits in the context of petroleum refining operations.

2   METHODOLOGY

The preparation of gamma scanning investigations for the column did not require many things, just access scanning outside the column from top to bottom. We used some types of equipment in this inspection, such as a gamma radiation source (^{60}Co; 1.74 GBq), radiation detector NaI(Tl), panoramic collimator, winch, slink cable made of steel, rate meter, pulley, roll meter, computer/laptop (data display), and personal communication equipment.

The implementation of gamma scanning was divided into 3 segments, based on that configuration of trays. Scans were carried out from bottom to top per 50 mm. The time of retrieval of each data was 3 seconds (C/3s). The measurement parameters presented in Table 1, and the scan orientation is shown in Fig. 1. The scan lines were very carefully selected to accommodate the investigation on all trays and they also adapted to external column condition that became obstacles to the probes. Scan orientation detail is summarized in Table 2.

Table 1. Measurement parameters.

Segment	ID (mm)	Height (mm)	Tray type	Number of tray	Source (activity)	Counting time
1	8900	45900	Four-pass	1 tray (Tray #28)	60Co (1.74 GBq)	3 Second
2	8900	45900	Two-pass	4 trays (Tray #29-#32)	60Co (1.74 GBq)	3 Second
3	8900	45900	Donut-Disk	6 trays (Tray #33-#38)	60Co (1.74 GBq)	3 Second

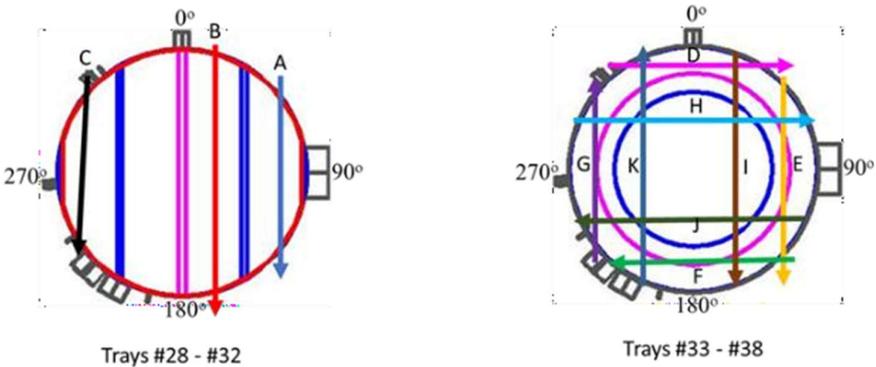Trays #28 - #32   Trays #33 - #38

Fig. 1. Column scan orientations (Top view).

Table 2. Column scan orientations detail.

Scan	Detector Position	Gamma Source Position	Scan Profile Color	Trays Number
A	47°	133°		#28 - #32
B	14°	166°		#28 - #32
C	308°	232°		#28 - #32
D	324°	37°		#33 - #38
E	126°	54°		#33 - #38
F	144°	216°		#33 - #38
G	306°	234°		#33 - #38
H	292°	68°		#33 - #38
I	158°	22°		#33 - #38
J	112°	248°		#33 - #38
K	338°	202°		#33 - #38

3   RESULTS AND DISCUSSIONS

The scan profiles are presented graphically in Fig. 2 - 8, in which the transmitted radiation intensity is plotted with respect to elevation. Since the column is a trayed-type column, the existence of the tray will be recognized as a narrow shape of significantly low radiation intensity on the scan profile.

As best as possible, the scan lines avoid external features such as manholes, ladder support, pipe support, platforms, nozzles, and transducers. However, some of these obstacles were not avoidable and interfered with the gamma transmission. It can lead to a significant reduction in radiation intensity and their presence complicates the interpretation of the results. In this context, the features are marked in the figures.

Scan A, B, and C as shown in Fig. 2 are to detect trays #28 - #32. The data shows that trays #28 - #32 are detected and they are in their position. Trays # 29 - #32 carry approximately the same amount of liquid, whereas tray # 28 holds a relatively large amount of liquid. There are no significant problems and these trays functioning properly according to scan data.

Scan D and E are shown in Fig. 3. Scan D is to detect the performance of trays #33 - #38. The data shows that trays #33 - #38 are detected as indicated by consecutive scan patterns with the same space distance between adjacent tray's positions. Trays # 33 - #38 carry approximately the same amount of liquid. According to the scan data, these trays are functioning properly. Moreover, the liquid level is detected at an elevation of 1,450 mm from TL.

The aim of scan E is to detect the performance of trays #33 - #38. The trays #33 - #38 and their position are detected as indicated by consecutive scan patterns with the same space distance between adjacent trays. Trays # 33 - #38 carry approximately the same amount of liquid. There are no problems encountered from this scan data.
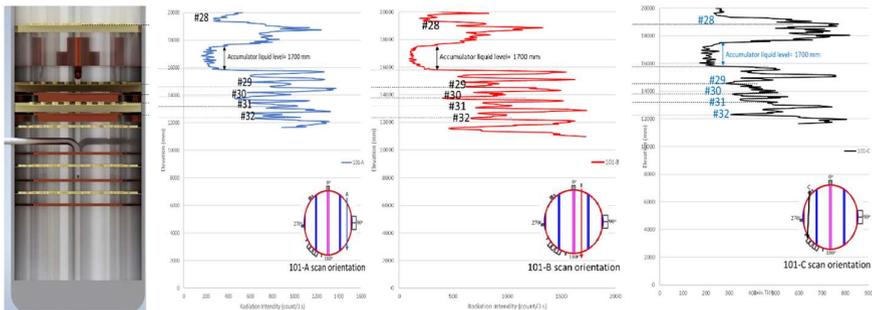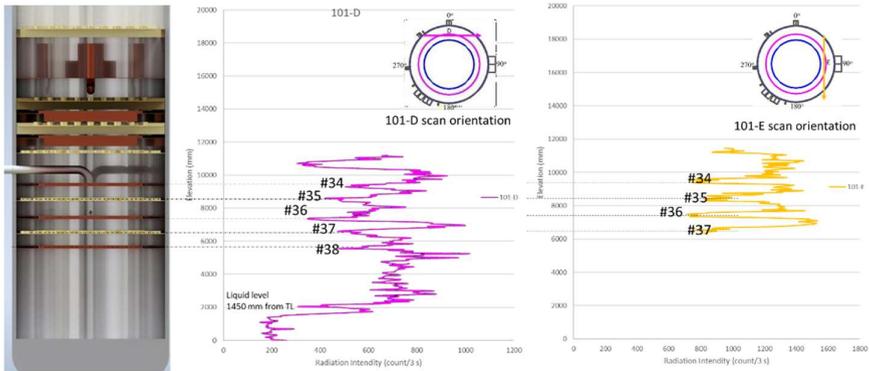

Fig. 2. Scan data A–C.
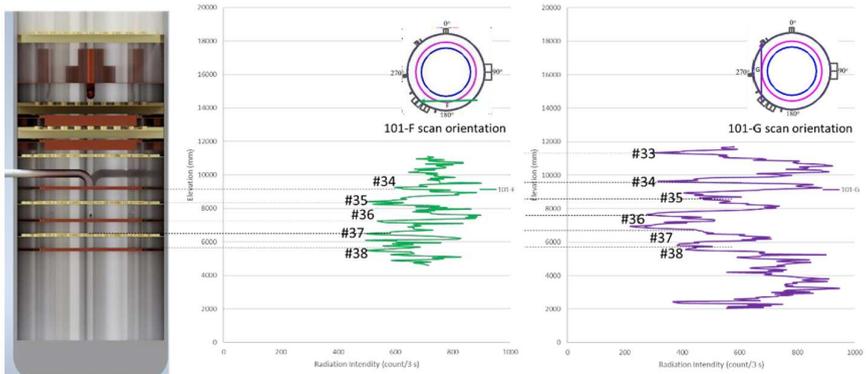
Fig. 3. Scan data D and E

Fig. 4. Scan data F and G

Scan F and G are shown in Figure 4. The scan data F is to detect the performance of trays #33 - #38. Both trays and their positions are detected as indicated by consecutive scan patterns with the same space distance between adjacent tray's positions. Trays # 33 - #38 carry approximately the same amount of liquid. These trays are working properly as viewed from the scan data.

The scan data G is to detect the performance of trays #33 - #38. The data shows that trays #33 - #38 and their position are detected as indicated by consecutive scan patterns between adjacent tray's positions. Trays # 33 - #38 carry approximately the same amount of liquid. These trays function properly according to scan data. The scan data H is to detect the performance of trays #33 - #38 as shown in Figure 5. Both trays and their positions are detected as indicated by consecutive scan patterns with the same space distance between adjacent tray's positions. Trays #33 - #38 carry approximately the same amount 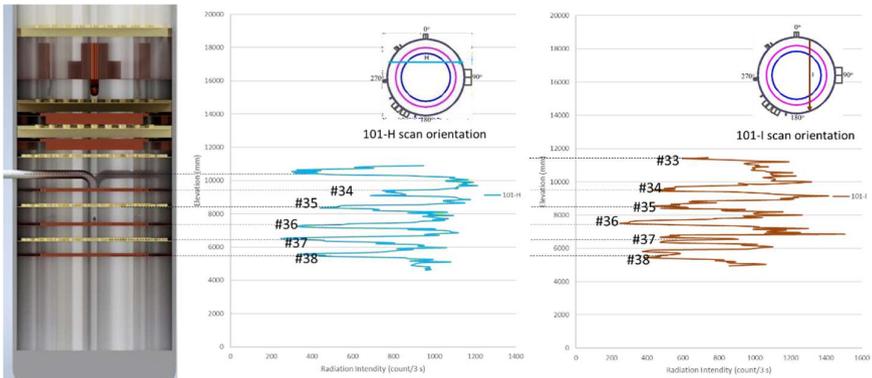of liquid. These trays work properly based on scanning data. The Tray #34 pattern shows the radiation intensity is higher than others, suspected partially damaged at that position.

The scan data I is to detect the performance of trays #33 - #38 as shown in Figure 5. Both trays and their positions are detected as indicated by consecutive scan patterns

with the same space distance between adjacent tray's positions. Trays # 33 - #38 carry approximately the same amount of liquid according to the scan data.

Figure 6 presents the scan data J and K are to detect the performance of trays #33 - #38. Both trays and their positions are detected as indicated by consecutive scan patterns with the same space distance between adjacent tray's positions. Trays # 33 - #38 carry approximately the same amount of liquid. These trays work properly by referring scan data.

Fig. 5. Scan data H and I
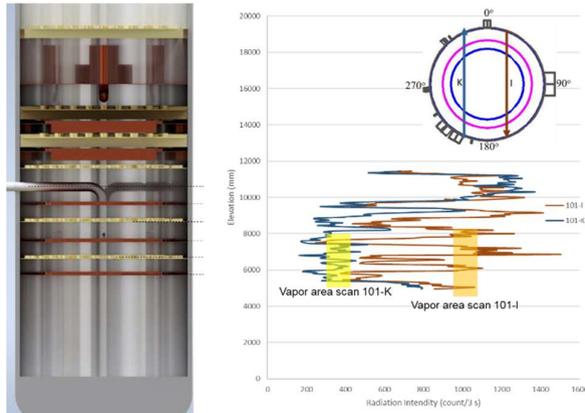

Fig. 6. Scan data J and K

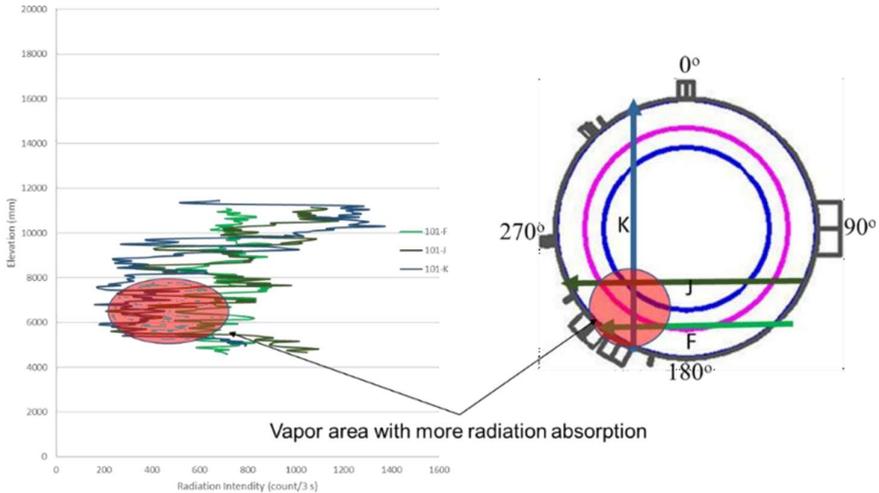**Fig. 7.** Comparison of K and I scan data.

Fig. 8. Comparison of F, J and K scan data.

Figure 7 is intended to compare the K and I scan data, because there is a considerable difference in radiation intensity profile, mainly in the area trays #37 and #38. As can be seen, radiation intensity at the scan line K is lower compared to its counterpart on profile radiation intensity obtained from the scan line I. Lower radiation intensity indicates more gamma rays are absorbed by materials in this area. It is believed that there are problems in the area between trays #37 and #38. Meanwhile, the profile of radiation intensity shown by trays #33 - #36 are considerably similar, indicating that there is no problem in this area.

Figure 8 is to emphasize the location and source of the problem based on the interpretation of Figure 7 above. Lower profile intensity in the scan line K indicates the presence of the tray's material and fluid derived from tray #37 that fell onto tray #38.

In this regard, tray #37 is suspected to be partially damaged and could not hold fluid on it.

There is a suspicion of a material that absorbs gamma radiation at a position as shown in Fig. 8. The radiation- absorbing material can be massive water flowing in the area or unknown material like coke or others.

4   CONCLUSION

The gamma-ray scanning technique has been applied to determine the condition and performance of tray #28 -#38 in the distillation Column. Eleven measurements have been conducted to determine the condition of the trays. The measurement concludes that all trays are still in their positions, Trays #28-#36 are functioning properly, there is suspected partial damage at tray #34. Tray #37 was suspected to have suffered partial damage so that it could not hold the fluid on it. Damage to tray #37 causes an impact to tray #38 due to fluid spills and material faults on tray #37 resulting in flooding on tray #38. There is a material that absorbs the gamma radiation observed in scan 15-C-101-F, J, and K as shown in Figure 8. It can be caused by massive water or unknown material like coke.

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