A quantitative approach to investigate downpour condition of distillation column using gamma beam radiation

F R Ningsih¹, Gama W N², and Wibisono¹

¹ Center of Isotopes and Radiation Application, National Nuclear Energy Agency
² PT Pertamina RU III Plaju

*Corresponding author: wibifh@gmail.com

Abstract. The area underneath the downcomer, part of distillation column is called the downpour area. If a tray deck troubleshooting like corrodes, it often first holes through in the downpour area. This will cause flooding due to the downcomer back up. An investigation of the crude distillation column was performed using an integrated system of photomultiplier detector and collimated gamma beam radiation. Gamma beam penetrated the object material as a transmitter of the radiation signal and will be accepted by the detector as its receiver. The main construction of this distillation column consists of 33 trays where each tray has two downpours and an accumulator. Distillation can be used to separate multi-component mixtures of crude oil. Many variables such as column pressure, temperature, size, and diameter are determined by the properties of the feed and the desired products. The measurement utilizes 75 mCi gamma activity and panoramic collimation design of the photomultiplier detector. This two equipment are aligned oppositely, and set on different four orientations scans, in order to obtain the condition of downpour system at each tray. Resolution scan of 5 cm each step from the bottom level to 34 m height. The duration time to measure radiation intensity is 3 seconds for each step. The quantitative result indicates abnormal flooding on the bottom segment tray #1 to #4. Abnormal condition is also identified as collapse tray, at tray #6. The quantitative approach has successfully determined the downpour condition in the distillation column.

1. Introduction

In the tray tower, liquid flows in downward following gravitational force but it flows against the pressure [1]. For a specific reason, troubleshooting like flooding in the distillation column may be identified if the liquid holds up on the tray increase to certain beyond of the standard [2]. Jet flooding caused by liquid-vapor mixture touches the next above tray [3]. The area underneath the downcomer is called the downpour area. If a tray deck corrodes, it often first holes through in the downpour area. This will cause flooding due to the downcomer back-up [4]. Slightly different with the downpour, if the liquid level in downcomer tray rises above the weir, it is called downcomer flooding [5].

Commonly action needed due to this condition by reducing pressure difference. For some reasons, this case is still continuing, and give an impact on tray performance. Therefore, the column will be operated by minimum capacity or decreasing production capacity. It is important to do some investigation for monitoring flooding conditions [6]. There are no inspection methods that can be monitor flooding because it must be observed in operation condition or online inspection [7]. Finally, gamma beam radiation technique becomes a quantitative approach to investigate several cases in the unit process [8].
Figure 1. The relationship of intensity and thickness of material

Based on figure 1, the right side describes profile scan for each elevation of the column. The curve also explains the condition of internal process and structure when the column in operation mode. The left side provides the amount of radiation intensity or gamma beam after penetrating object material. The thickness function depends on the graphic result. This paper will give explanation and elaborate on how gamma beam radiation can identify internal condition while operation mode.

2. Description of The Experiment and Research Methods
This object was a crude distillation column unit with a various density of hydrocarbon. The construction of internal diameter is 4 m and the vertical distance from TL to TL is 33.55 m. The elevation of the first TL measured from the ground is 3.6 m. This main construction consists of 33 trays where each tray has two downpours and an accumulator.

Figure 2. Main structure of crude distillation unit

In a distillation column, liquid and vapor are contacted while passing over and through trays. This means vapor and liquid phases are assumed to reach equilibrium as they interact over the tray [1]. However, in practice the density of these hydrocarbon materials is varied in one condition, and shall be distinguished by gamma ray through intensity profile.
Referring to the mechanical image determined the starting point of the scan and the orientation of the source and gamma detector. Two pulleys placed at the highest position will be scanned each in the orientation of the source and detector. The source collimator and detector collimator are hung on their respective pulleys and tied to the whincer. The position of the detector collimator and source are set at the initial position of the scan and both are on the horizontal line. The initial position is determined as the 0 cm position. The point 0 cm coincides with TL at the bottom.

Figure 3. Scan orientation

S1 to S4 scan was performed on the bottom segment, focus on the elevation 0 – 950 cm to identify liquid level conditions, tray #1 to #4, tray #5 - #9, and the accumulator. Whereas in the top segment, at an elevation of 950 cm to 3000 cm to identify mechanical structure of tray #10 to #33.

The measurement of bottom segment began with setting position of S1 scan, where the orientation of radiation source was 282° and detector was 41° horizontally by distance 100 cm below the TL. At this position, the intensity of radiation was measured for three seconds, then recorded as a function of intensity I to elevation y denoted I(y). The measurement continued by increasing position of the two sources and the detector at -95 cm elevation, then it should be repeated until reach elevation of 950 cm. Scan codes of S2, S3 and S4 were the same procedure according to the orientation of each scan.

Figure 4. Scanning orientation following downcomer orientation at each elevation
3. Result and Discussion

![Scan profile](image)

**Figure 5.** Data result for bottom segment

Scans S1 - S4 at elevation of 100 cm below TL showed low intensity. The intensity increased suddenly at elevation of 180 cm. This condition occurred because gamma rays penetrated liquid production in the bottom column. Liquid volume at the time of measurement can be described as information about online production capacity.

Radiation intensity decreased again at elevations of 200 and 240 cm due to the mechanical structure. At an elevation of 300 cm equal with position of tray #1, the intensity decreased again to an elevation of 460 cm or aligned with tray #4. Four profile scans in this area explained the phenomenon of identical absorption of radiation intensity. Referring to the drawing in this area, there should be 4 trays which mean there were 3 void areas above tray #1, #2, and #3. This profile can be suspected as flooding above all three trays and might be caused by liquid flow. This allegation was strengthened by observing the vapor under tray #1.

Scan profile in tray #5 has been confirmed in a normal position, in contrast with tray #6, the intensity of the radiation didn’t show that liquid absorbed above it. A typical tray profile as an accumulation of structural and liquid uptake appeared small and short on red and green curves, but quite normal on blue and black curves. Tray #6 suspected mechanical damage on the red and green sides.

The intensity curve under tray #7 was interrupted because blocked by platform. The profile above tray #7, presented by the red-green curve was lower than blue and black curves. This interpretation leads to an opinion that gamma rays were blocked by downpour, where there was no opposite condition occurring in scan profile above tray #8, where the intensity of green and red was higher than blue and black because gamma-rays in the blue and black orientation were blocked by downpour.

The accumulator identified in its position suitable with the mechanical drawing, and liquid level not exceeding the chimney above it.
4. Conclusion
Flooding occurs if vaporization rate of reboiler is higher, then liquid partially carryover by the vapors from below tray to above tray. If it is continuing then liquid hold up on the above tray increases and causes flooding. Measurement result showed that trays #52 to #47 and #21 to #1 were verified on its position, suitable with drawing reference. Flooding was observed at the tray #37-22, so fifteen trays sank and could not be identified. Tray #38 to #45 were not uniformed according to mechanical drawing. Liquid level above first accumulator was almost dried, in contrast with second accumulator which full of liquid, exceed the height of chimney. In conclusion, the analysis evinced that nuclear technology is suitable to be one of non-destructive methods in industrial scale.

Figure 6. Data result for middle segment

Green and red scans at elevations of 1600 cm to 3000 cm showed tray #15 to #33 in normal conditions, existed at their positions refered to the drawing. In this segment there are four platforms, therefore the four scan curves were broken. In general, interpretation of all trays in this segment did not experience mechanical problems, flooding or blockage that affects production quality.
Acknowledgements
The authors gratefully acknowledge the Center of Isotopes and Radiation Application (PAIR), National Nuclear Energy Agency of Indonesia. This work was supported by the company PT Pertamina Refinery Unit V Balikpapan. The main contributor for this paper are Ms. Firliyani and Mr. Wibisono. The members contributor is Mr. Gama.

References
[1] E. Magaril and R. Magaril, “Effect of pressure on the rectification sharpness in rectifying sections of tray distillation columns in oil and gas refining,” Sep. Purif. Technol., pp. 49–54, 2019.
[2] V. Wolf-Zöllner, F. Seibert, and M. Lehner, “Extended performance comparison of different pressure drop, hold-up and flooding point correlations for packed columns,” Chem. Eng. Res. Des., vol. 147, pp. 699–708, 2019.
[3] W. L. Luyben, “Dynamic simulation of flooded condensers,” Chem. Eng. Res. Des., vol. 118, pp. 12–20, 2017.
[4] P. Liu, Z. Yuan, S. Zhang, Z. Xu, and X. Li, “Experimental study of the steam distillation mechanism during the steam injection process for heavy oil recovery,” J. Pet. Sci. Eng., vol. 166, pp. 561–567, 2018.
[5] Z. Jiang et al., “Global optimization of multicomponent distillation configurations: Global minimization of total cost for multicomponent mixture separations,” Comput. Chem. Eng., pp. 249–262, 2019.
[6] X. Li, C. Cui, and J. Sun, “Enhanced product quality in lubricant type vacuum distillation unit by implementing dividing wall column,” Chem. Eng. Process. Process Intensif., vol. 123, pp. 1–11, 2018.
[7] W. Azmi, Bayu; Wibisono, “Portable Gamma Ray Tomography System for Investigation of Geothermal Power Plant Pipe Scaling.” IEEE Press - International Conference on Advanced Logistics and Transport, New York, 2017.
[8] Wibisono, B. Azmi, and Z. Lubis, “Investigation on Aluminum Pall Ring DA-302 Ethane Washer Tower used Gamma Scan and Gamma Tomography Technique,” Pertem. Ilm. Iptek Bahan, no. Lll, pp. 218–225, 2016.
[9] M. N. Boone et al., “High spectral and spatial resolution X-ray transmission radiography and tomography using a Color X-ray Camera,” Nucl. Instruments Methods Phys. Res. Sect. A Accl. Spectrometers, Detect. Assoc. Equip., vol. 735, pp. 644–648, 2014.
[10] M. Mamtimin, F. Harmon, and V. N. Starovoitova, “Sc-47 production from titanium targets using electron linacs,” Appl. Radiat. Isot., vol. 102, no. April, pp. 1–4, 2015.
[11] P. D. F. Forms et al., “Sc-46 Radionuclide Fact Sheet,” vol. 46, pp. 9–10, 2019.
[12] G. Audi, F. G. Kondev, M. Wang, W. J. Huang, and S. Naimi, “The NUBASE2016 evaluation of nuclear properties,” Chinese Phys. C, vol. 41, no. 3, pp. 1–138, 2017.
[13] R. Awad, A. Al-Zein, M. Roumie, and I. H. Ibrahim, “Synthesis and characterization of Tl-1223 substituted by scandium,” J. Mater. Sci. Technol., vol. 29, no. 11, pp. 1079–1084, 2013.
[14] J. R. De Laeter et al., “Atomic weights of the elements: Review 2000 (IUPAC Technical Report),” Pure Appl. Chem., vol. 75, no. 6, pp. 683–800, 2003.