Evaluation of the fractionation process on aviation turbine fuel production using nuclear technology

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Abstract. The role of nuclear technology not only for electricity as clean energy but also for a tool to evaluate the process in the refinery unit. Fractionation columns are designed to achieve the required separation of fluid mixtures or miscible liquids efficiently. A troubleshooting was reported on aviation turbine fuel production in the refinery unit. Due to this report, an evaluation was performed at fractionator for aviation turbine fuel production to investigate suspected areas. The specification of the unit is height of 44.4 m, internal diameter ID: 4.4 m, and consists of 52 trays, three accumulators, nine platforms. The radiation is collimated and assumed by a point source meanwhile, detector is given a panoramic window. Radiation counting in every point with step 50 mm to gain quantitative data regarding process inside the column. The nuclear technology has successfully revealed the troubleshooting column by the principle: attenuation radiation. Basically, attenuation value depends on the material which penetrated by gamma-ray. Based on six orientation the experiment successfully found flooding cases, misorientation trays, and dried chimney. Overall, the analysis proved that nuclear technology is suitable to be one of non-destructive methods in industrial scale. Future study is to provide three dimensional image by combining tomography and gamma scanning technique.

1. Introduction

Nuclear technology has been utilized not only to generate electricity as a sustainable energy, but also for a non-destructive tool to evaluate process unit in oil and gas industry [1]. Radiography is one example of the most used in engineering field, for welding or casting test [2]. Quite different with radiography, some experiments used gamma scanning to perform on-line troubleshooting, optimization and predictive maintenance of trayed or packed distillation columns, without interfering with the process or tower internals in any way [3][4]. The main advantage of nuclear technique is online investigation, means process unit doesn’t need to be shut down when evaluation is being run. In order to diagnose the operation condition by measuring a level, distribution or flow pattern of process media in mixed phases without shutting down the process inside column [5]. A distillation column is a series of equilibrium flashes with two feeds and two product steams. In fractionation column there is an overall increase that different on each tray. Various heating aims to purify the distillate for trays below it [6]. The evaluation aims to identify the trays condition and internal structure completeness, by the concept attenuation of radiation intensity on various material hydrocarbon [7].
According to the figure 1, left side shows the real image of material structure, meanwhile the right side explains intensity profile of radiation. The thickness function depends on the graphic result. This study will describe further about the case of fractionation column in refinery unit, which produce aviation turbine fuel by specific parameters for each segment of column.

2. Description of The Experiment and Research Methods

2.1. Fractionation process

This column produces aviation turbine fuel (ATF) with various density of hydrocarbon. The construction of internal diameter is 4.4 m and the vertical distance from TL to TL is 44.4 m. The elevation of first TL measured from the ground is 5.6 m. This column consists of 52 trays and 3 accumulators.

In a distillation column, liquid and vapour are contacted while passing over and through trays. This means vapour and liquid phases are assumed to reach equilibrium as they interact over the tray [8]. However, in practice the density of these hydrocarbon materials is varied in one condition, and shall be distinguished by gamma ray through intensity profile.
2.2. Gamma radiation source Sc-46

Sealed radioactive sources are usually used for gauging tools in oil and gas industry. As of 2003 the isotopes such as Iridium-192, Cobalt-60, Cesium-137 are most commonly used by the oil and gas industry because they are easily observed [9]. The attenuation of these gamma rays gives an accurate measure of formation density. In contrast with those sealed sources, Scandium (Sc) are friendly used for medical therapy needs especially in Indonesia [10].

The isotopes of scandium range in atomic weight from 38 u (the dalton or unified atomic mass unit) (36Sc) to 62 u (62Sc). Half-life of this radio isotopes is 83.83 days, type decay $\beta$- with the maximum energy 0.357 MeV. Beside beta particle, Sc-46 emits gamma rays 0.889 MeV (100%) and 1.121 MeV (100%). Hazard category is low, as long as the activity 1 mCi to 100 mCi [11].

The dose rate from betas at 1 cm from an unshielded 1 mCi (dried sample) of Sc-46 (assuming no backscatter or self absorption in the source) is 420 rads per hour [12]. The exposure rate at 1 cm from 1 mCi due to photons is 10.9 Rads per hour [11]. Dose rates vary directly with activity and over short distances inversely with the square of the distance from the source. Maximum range of the betas is 0.03 inches in plastic [13]. The half value layer for the gammas is approximately 1.3 cm of lead.

### Table 1. Several examples of Scandium radioisotopes and its characterization [14]

| Nuclide   | Z   | N   | Isotopic mass (u) | Half-life  | Decay mode | Daughter isotope | Spin and parity |
|-----------|-----|-----|-------------------|------------|------------|------------------|-----------------|
| $^{45}$Sc | 21  | 24  | 44.9559119(9)    | Stable     | 7/2−       |                  |                 |
| $^{45m}$Sc| 21  | 24  | 12.40(5) keV     | 318(7) ms  | IT         | $^{46}$Sc       | 3/2+            |
| $^{46}$Sc | 21  | 25  | 45.9551719(9)    | 83.79(4) d | $\beta^-$   | $^{46}$Ti       | 4+              |
| $^{46m1}$Sc | 21 | 25  | 52.011(1) keV    | 9.4(8) µs  | IT         | $^{46}$Sc       | 1−              |
| $^{46m2}$Sc | 21 | 26  | 142.528(7) keV   | 18.75(4) s | IT         | $^{46}$Sc       | 1−              |
| $^{47}$Sc | 21  | 26  | 46.9524075(22)   | 3.3492(6) d | $\beta^-$   | $^{47}$Ti       | 7/2−            |
| $^{47m}$Sc | 21 | 26  | 766.83(9) keV    | 272(8) ns  |            |                  |                 |

2.3. Scanning system

The principle of analyzing is the radiation intensity measured by detector after passing an object show in the figure 3 and given by this following equation [15]:

$$ I_x = I_0 e^{-\mu x} $$  \hspace{1cm} (1)

Where $I(x)$ = Intensity of gamma rays through material (cps); $I_0$ = initial intensity of source (cps); $\mu$ = linear attenuation coefficient (m$^{-1}$); $x$ = thickness of shielding material (m)
The measurement method uses the gridding method. The measurement orientation is divided into three sections, top, middle and bottom segments. This takes into account the orientation of the downcomer in each tray. The scanning direction should not contact with downcomer in order to easier interpretation. In fact, in certain circumstance this rule can not be avoided, considering the external structure and safety aspects.

**Figure 4.** Scanning orientation following downcomer orientation at each elevation

Based on mechanical drawing, tray #1 to tray #19 has a downcomer that crosses 0 and 180 degrees. Downcomer which is located on the 0 side, precisely from angle of 316° to 44°. The red line represents the scan orientation for different segment. On the bottom segment, represents by SB1 and SB2 scan code to explain scan direction from angle 90° to 270°. The same rule also applies to tray #35 to tray #52 which has the downcomer direction 0°-180°. Middle segment represents by SM1 and SM2 scan code. The distance between these two scans is 300 cm. The red line is a plan for gamma ray shots to identify the status of these trays. Therefore, it can be concluded, the more orientation of gamma ray shots, the closer the distance or space is verified, so the sharper gridding resolution is obtained. The last for top segment is presented by ST scan code.

Data retrieval is taken by hanging gamma emitter and scintillation detectors on opposite sides of the tower wall surface. Data collection starts from 200 cm below TL. The 0-reference point is the TL elevation. The scan is carried out from the bottom to the top of the tower, with a 5 cm delta / step measurement. The duration of data retrieval is 3 seconds at each point, and is repeated at least three times to obtain more valid statistical data.

| Table 2. Scan code of orientation |
| No | Scan Code | Radiation Source (°) | Detector (°) |
|----|-----------|----------------------|--------------|
| 1  | SB1       | 57                   | 303          |
| 2  | SB2       | 42                   | 138          |
| 3  | SM1       | 318                  | 228          |
| 4  | SM2       | 48                   | 318          |
| 5  | ST        | 138                  | 222          |
3. Result and Discussion

![Figure 5](image)

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

The measurement results for the top segment are represented by ST scan code in the figure 5. The scan starts at elevation 3000 cm, and verifies the position of tray #19, #18, up to tray #11. Radiation intensity measured when gamma rays penetrate the tray is in the range of 1000-1500 counts per 3 seconds. As for the gas or vapor medium, the intensity is in the range of 3000 - 3500 count / 3s. For the liquid phase above the tray surface is difficult to verify the amount, because data scan steps every 5 cm while the height of the liquid or liquid gas interface above the tray is less than 5 cm. At 3550 cm elevation, the scan is skipped as far as 20 cm, because there is an external support that is blocking the data retrieval process, so the graph is interrupted. Besides tray #12 which is in a position of 3555 cm from TL, its existence cannot be verified.

At 3700 cm elevation a scan was observed for acc #1, but in subsequent data intensity was read through the gas / vapor phase, so it can be concluded that acc #1 was in very thin, or almost dry conditions. Based on experience, the intensity of the accumulator will produce a graph that rises slowly because of the liquid and liquid gas interface. However, this does not appear in acc #1.

Tray #10 to tray #1 is completely observed in its position. This is observed from the results of the graph that has a sharp pattern, so that it can be verified that the gas and gas interfaces are present on each surface of these trays. Lower intensity under tray #2 because gamma rays are absorbed by external structures. The difference in tray chart patterns #1 - #10 with tray #11 - #19 is due to the intensity measured in different counter systems. Although there are differences in values, but in conclusion the existence of trays match with technical drawing references.
The measurement results in the middle segment of the fractionator column showed significant data. Middle segment scan starts from elevation of 1300 cm to 2900 cm, to verify acc # 3 to tray # 21. Based on the six scans the liquid level above the # 3 accumulator was observed to flood tray # 27 - # 26. Then between tray # 25 and # 26 the measured intensity shows the gas phase, but above tray # 25 shows flooding, that is, the liquid level almost touches accumulator # 2. The intensity of the measured radiation is very low, which is in the range of numbers 30-70 count / 3s. This value is assumed to be gamma ray radiation penetrating liquid as thick as the diameter of the tank, because the absorption of radiation is very high. The phenomenon of the low value of the intensity of this radiation is often found when scanning in the field, and is strongly suspected to be caused by flooding. Even though the volume suspected to be flooding contained solid material, this value could no longer be reduced to near 0 because there was a rounded background count.

Meanwhile, the liquid contained above accumulator # 2 was observed to be above the height of the chimney above it. Tray # 22 and # 21 were observed normal while tray # 20 was inaccessible. The difference in the value of gas intensity on scan A is due to the position of scan A which is located more to the edge / outside of the column.
Data graphic according to figure 7 show the liquid level measured was 75 cm above TL. Tray #47 to #52 are indentified on its position or elevation. On the other hand, tray #45 to #38 show abnormal configuration. Trend line of graphic couldn’t be distinguished either vapour, liquid or solid material. This can be assumed these trays are not at their elevation or may be collapse.

4. Conclusion
A study was conducted to evaluate the fractionation process on the production system of aviation turbine fuel. The measurement method used the principle of attenuation of radiation through a column object consisting of several mechanical structures, either internal or external structure. The collimated radiation source and the panoramic window detector system have identified a liquid level, 75 cm above TL. 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. Next step after this successfully experiment is how to present process inside the column including the troubleshoot in three dimensional imaging. It combains tomography technology which give you cross sectional image and gamma scanning technique. This obviously needs a huge numners of detectors and long term experiment.
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