On-line Diagnosing on Trayed Column of Etylene Plant Using Gamma Ray Scanning

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ABSTRACT

Nuclear based technology called gamma scanning technique found its application for troubleshooting and diagnosing industrial process performance. The success of application of the gamma scanning technique is attributed to its unique ability in providing information which is cannot be obtained by any other techniques. One of the most prominent advantages of the gamma scanning technique was demonstrated by implementing this technology for scanning caustic/water wash tower DA 202 which was running in normal condition of operation. The DA 202 tower is trayed column having diameter of 4.2 m and height of 40 m. The scanning work has been performed using 70 mCi ^{60}Co isotope as gamma emitter and scintillation detector as radiation counter to investigate condition of ten trays, starting from tray # 13 at elevation of 35050 mm to tray # 4 at elevation of 26950 mm above ground level. Scan data show that all trays were in their position. Tray # 4 to tray #10 were functioned properly and carried approximately the same amount of liquid. Light flooding on tray # 11 and heavy flooding on tray # 12 were identified. Partial flooding was identified on tray # 13. Further examination at the time of shutdown it was found that the liquid flooding on tray # 12 was caused by presence of a bucket covered with solidified mud.

INTRODUCTION

Ethylene is produced in petrochemical industry by steam cracking in quench tower. In this process, gaseous or light liquid hydrocarbons are heated to 750-950°C, inducing numerous free radical reaction followed by immediate quench to stop these reactions. This process converts large hydrocarbon chains into smaller ones and introduces unsaturation condition. Ethylene is then separated from the resulting complex mixture by repeating compression and distillation. Caustic/water wash tower DA 202, is one of critical components in continuous ethylene production plants of large petrochemical industry located in Banten province. The column is designed to quench the radical reaction in ethylene line production. Problem identified was pressure increasing of the column [1]. Problem in this column leads to serious consequences to the plant operation and hence the quality of the product. It is urgently to find out the proper method in order to know what is really happening inside the column. The gamma ray scanning technique as troubleshooting tool was selected to examine the cause of the problem in this column.

The gamma scanning technique is very suitable to be implemented for troubleshooting and diagnosing of technically complex, continuously operating industrial plants. The advantage of the gamma scanning technique is that this technique is applied just at the time when the plant is in operation. Petrochemical and chemical process industries are the main users and beneficiaries of the column scanning technology [2]

In engineering applications, gamma scanning technique has been used for inspection of various processing units of industrial plants and has been reviewed [3,4] and documented [5]. Gamma scanning technique with one source-one detector was used to for multiphase flow regime of hydrocarbon in the horizontal pipeline transport [6], distillation columns [7,8], and debutanizer of Fluidized Catalytic Cracking Unit (FCCU) in petroleum plant [9]. The gamma scanning technique was also used for characterization of radioactive waste in the container [10,11]. In combination with tomographic system, gamma scanning was used to assay radioactive waste [12].

In this paper on-line measurement of radiation intensity using gamma scanning technique is

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demonstrated to figure out the source of the problem in trayed column of quench tower DA 202. The diameter of the column is 4.2 m and the height is 40 m. The gamma emitter, ^{60}Co with activity 70 mCi, and scintillation detector were used to scan the column from the elevation of 26250 mm to the elevation of 35950 mm above ground level which cover tray # 13 to tray # 4. Selected data of measurement are presented come with the conclusion. The problem is identified based on measured data. To my understanding, publications related to this matter are rare, event in handbooks, therefore it is hope that this paper may contribute for dissemination of gamma scanning technology as promising tool for industrial application, especially in developing countries.

Theory of gamma scanning

Gamma scanning work is carried out by moving concurrently a small suitably sealed gamma radiation source and scintillation detector, NaI(Tl), along the exterior side of the column, as schematically presented in Fig 1. During the period of investigation, the radiation source was encapsulated and placed permanently in a special housing and make no contact with a radiation detector or with the process materials in the column. A source holder with an appropriate panoramic collimator was designed to exposure the column. Scintillation detector on the other side of the column was employed to capture the radiation intensity emitted by the radiation source. Interaction of the gamma radiation with medium of interest in the column will produce change intensity of the beam which correlated to the properties of the medium [13,14].

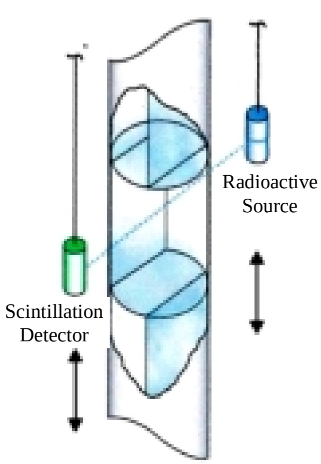

Fig.1. Schematic principle of gamma scanning measurement.

The theory of gamma scanning technique is based on the fundamental relation [4,5,13-15]

$$I = BI_{\circ} \exp(-\mu\rho x) \tag{1}$$

where I (cps) is the intensity of radiation transmitted through the material. I_o (cps) is the intensity of incident radiation. μ (m^2/kg), ρ (kg/m^3) and x (m) are the mass absorption coefficient, the density and the thickness of medium respectively. B is buildup factor (dimensionless). In practical application each medium inside the column is assumed as linear and isotropic. By using collimated beam, it is also assumed that intensity contribution from scattered radiation is considered none, therefore the buildup factor is set equal to 1. From these assumptions, Eq. (1) is safely stated as:

$$I \equiv I_{\circ} \exp(-\mu_l x) \tag{2}$$

where μ_l is linear constant and apply for each medium. It is worth to note that gamma radiation for column investigation should be capable of penetrating the wall thickness of the column and the medium of interest. From the scanning work a density profile of the internal contents of the column is obtained. For trayed column, the following statements can be derived [8]:

- When the gamma radiation goes through a medium containing a tray filled of aerated liquid, the incident beam is partially absorbed and the radiation quantity reaching the detector is relatively small.
- When a radiation beam goes through a tray, most part of incident radiation is absorbed and the detected signal is weak.
- When a radiation goes through steam, only a small amount of incident radiation is absorbed through which high radiation intensity transmitted to the detector.

These statements can be made for analyzing possible mechanical damage of components inside the column such as flooding, blockages, damaged tray and other process anomalies.

EXPERIMENTAL METHODS

Column scanning work is generally performed without any preparation to the column. All that required is the access way to the uppermost platform. No insulation needs to be removed, and the scan does not interfere with the operation of the column. In many situations, most columns have convenient platforms or walkway on which source and detector can be suspended, but in certain situation some additional support such as scaffoldings are required.

Equipments for scanning experiment are: 70 mCi ^{60}Co radiation source, electro-mechanical control system equipped with stainless-flexible slink cable for controlling movement of detector and source, scintillation detector and data acquisition system for data transmission, personal radiation protection aids, laptop computer for data display and stationeries.

The scheme called grid scan has been performed in this experiment by conducting several radiation intensity measurement from various scan orientations. Scan orientation or scan position describes the placement of radiation source (abbreviated as **S**) and scintillation detector (abbreviated as **D**) for a certain direction. The scan orientation is measured with respect to north direction of the plant (NP). The grid scan of experiment is summarized in Fig. 2.

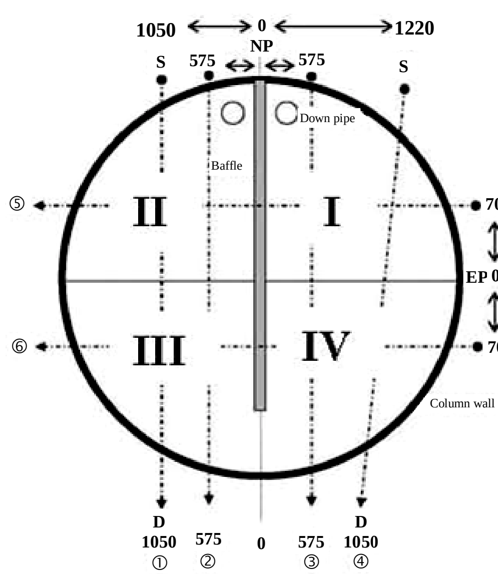

Fig. 2. Schematic scan orientation. Note that (**S** → **D**) is direction of measurement. For example, ③ is scan of position 3.

The gamma scanning work on caustic/ wash water tower DA 202 was performed as follows: both radiation source and scintillation detector were put at the same level, separated by column construction. The center of flange of the third man-hole (at elevation of 26250 mm above ground level) was assigned as referenced point for starting level of measurement. To ensure that the source and the detector were maintained in the same horizontal level a single stainless-flexible slink cable was used. By utilizing an automatic electro-mechanical control system, the detector and the source were lifted up simultaneously at determined step approximately of 17.3 mm with delayed time 5 second for capturing radiation intensity. Throughout experimentation the operational condition parameters of the column such as feed-rate, temperature and other process parameters were maintained constant. Fixation of these conditions is very important to record any process changes during the time of the scan and to facilitate the interpretation of the scan profile if any anomalies were observed. The movement was stopped when the detector and the source reached close to end point of the measurement, just few mm above the fourth man-hole. During the scan processing, data captured by scintillation detector were monitored in laptop computer and then saved for subsequent data analysis.

RESULT AND DISCUSSION

The data of the scans are presented in Figs. 3 to 8. Material conditions inside of tower DA 202 were analyzed based on scan data. In order to meaningful interpretation a mechanical drawing of the DA 202 column was consulted as the reference. In this regard, scan data were compared with the mechanical drawing which reflect the condition of internal material in the column. Deduction from the scan data many parameters indicating column performance can be obtained.

Scan data of the caustic/ water wash tower DA 202 show that all trays were in their position as indicated by regular pattern having same spaced distance. Deep observation to each scan data indicated that three of the ten trays have experienced problems. Trays # 4 to tray # 10 were functioned properly. Serious problems were found on trays # 11 to # 12, whereas non-serious problem was found on tray # 13. Light liquid flooding on tray # 11 and heavy liquid flooding on tray # 12 were identified. In addition, presence of suspecting foreign material on tray # 12 was also observed.

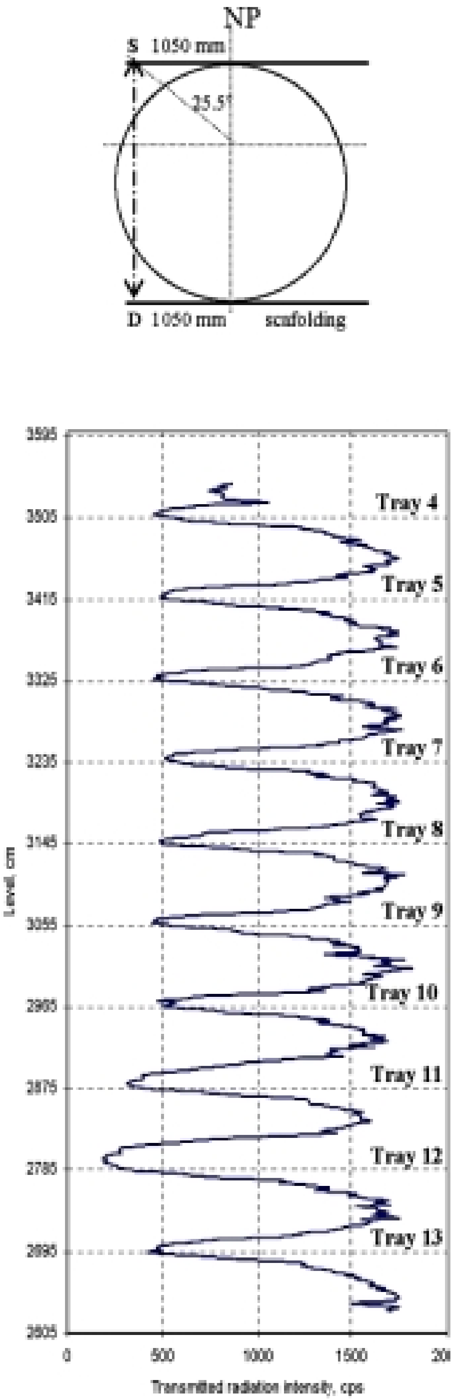

Fig. 3. Profile of tower DA-202 obtained from scan orientation 1. The source and the detector were positioned at 1050 mm (25.5°) and 1050 mm (154.5°) respectively. Trays # 4 to # 10 and tray # 13 were in position and carried approximately the same amount of liquid. Flooding on tray # 11 and tray # 12 were observed as indicated by their lower and wider scan curve.

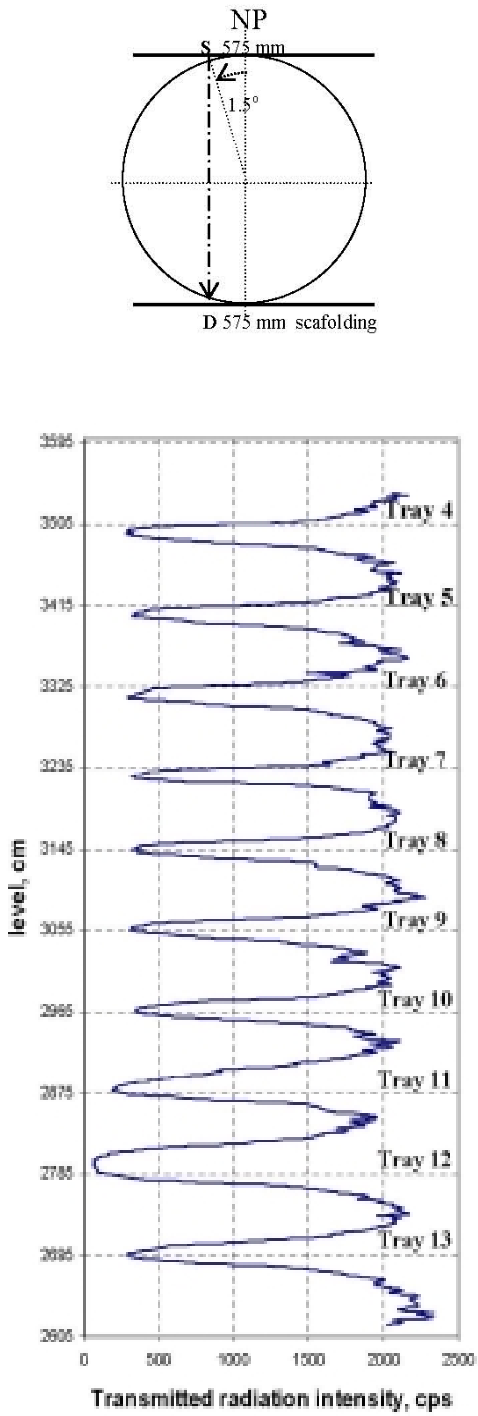

Fig. 4. Profile of Tower DA-202 obtained from scan orientation 2. The source and the detector were positioned 575 mm (1.5°) and 575 mm (178.5°) respectively. Trays # 4 to # 10 and tray # 13 were in position and carried approximately the same amount of liquid. Flooding on tray # 11 and tray # 12 were observed as indicated by their lower and wider scan curve.

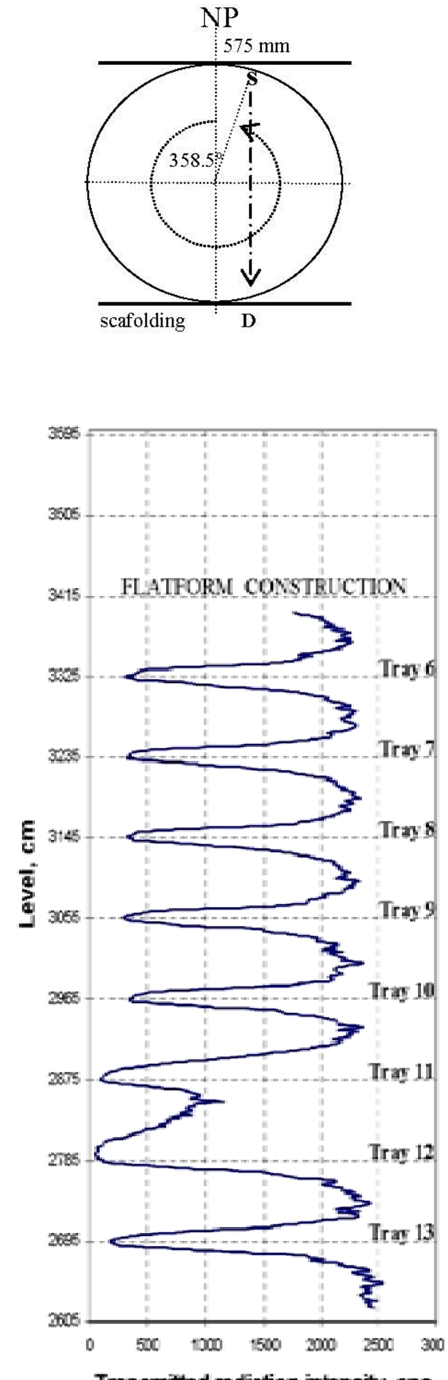

Fig. 5. Profile of Tower DA-202 obtained from scan orientation 3. The source and the detector were positioned 575 mm (358.5°) and 575 mm (181.5°) respectively. Trays # 6 to # 10 was carried approximately the same amount of liquid. Light flooding on trays # 11 and # 13 were observed. Flooding and solidified materials on tray # 12 was observed.

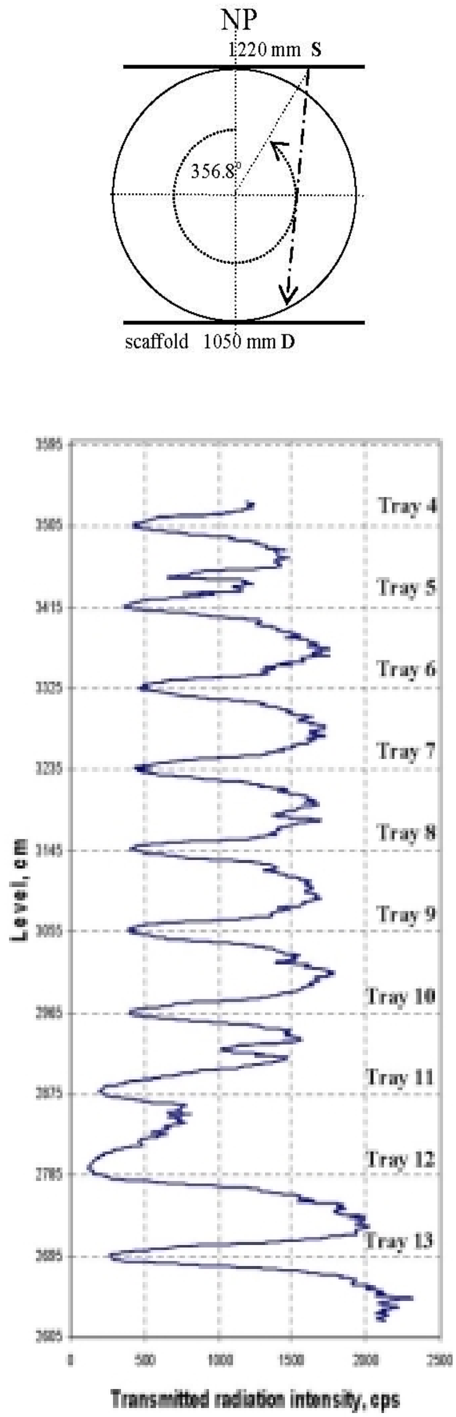

Fig. 6. Profile of Tower DA-202 obtained from scan orientation 4. The source and the detector were positioned 1220 mm (356.8°) and 1050 mm (182.7°) respectively. Trays # 4 to # 10 was carried approximately the same amount of liquid. Light flooding on trays # 11 and # 13 were observed. Flooding and solidified materials on tray # 12 were observed.

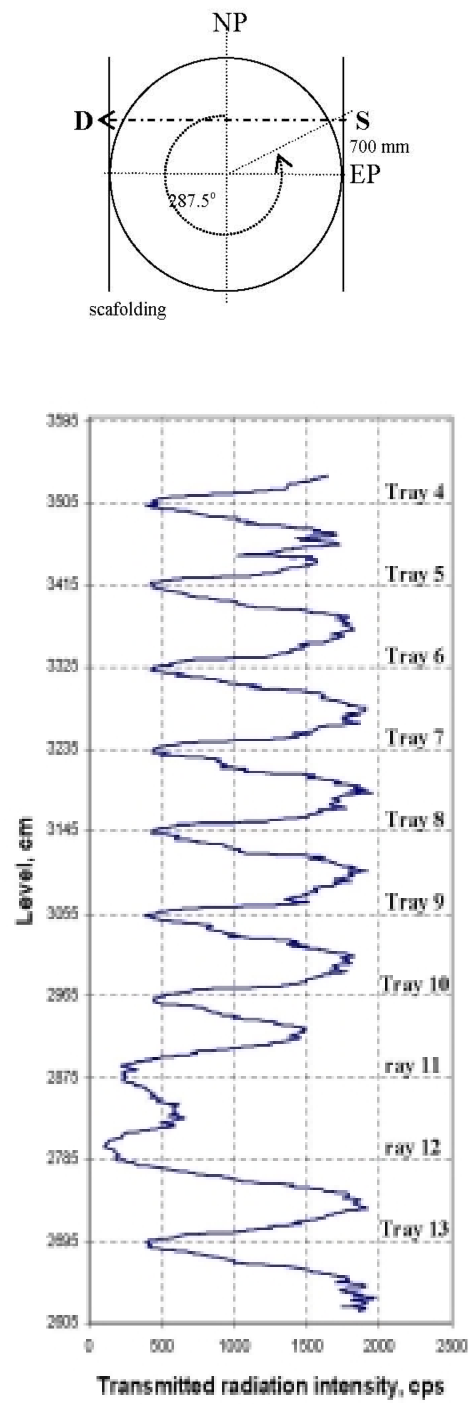

Fig.7. Profile of DA-202 tower obtained from scan orientation 5. The source and the detector were positioned at 700 mm (287.5^o) and 700 mm (72.5^o) respectively. Trays # 4 to # 10 was carried approximately the same amount of liquid. Light flooding on trays # 11 and # 13 were observed. Heavy flooding and solid material on tray # 12 was observed.

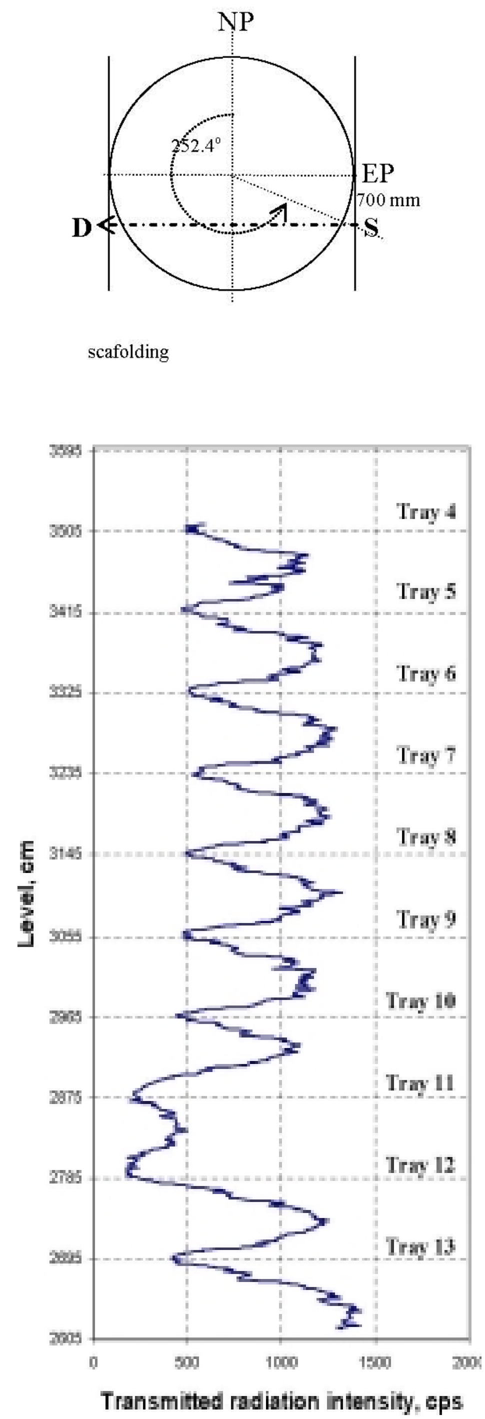

Fig. 8. Profile of DA-202 tower obtained from scan orientation 6. The source and the detector were positioned 700 mm (252.4^o) and 700 mm (107.6^o) respectively. Trays # 4 to # 10 was carried approximately the same amount of liquid. Light flooding on trays # 11 and # 13 were observed. Heavy flooding and solid material on tray # 12 was observed

It is important to observe in detail each data presented in Figs. 3 to 8. Light flooding on tray # 11 was approximately 30 cm height, justified by measuring the wide of inflected curve which corresponding to density change on the corresponding tray. The same method was also applicable for measuring the flooding level on tray # 12 though that the tray was not only containing liquid but also solidified material. If it is assumed that the solid material is fully settled or immersed in the liquid or mud, therefore the liquid thickness on tray #12 was approximately 40 cm. Conditions of all trays based on scan data is summarized in table 1

Table 1. Condition of trays based on scan data

Tray #	Tray condition	Viewed from scan orientation
4	Normal	①②③④⑤⑥
5	Normal	①②③④⑤⑥
6	Normal	①②③④⑤⑥
7	Normal	①②③④⑤⑥
8	Normal	①②③④⑤⑥
9	Normal	①②③④⑤⑥
10	Normal	①②③④⑤⑥
11	Light flooding	①②③④⑤⑥
12	Heavy flooding and foreign material	①②③④⑤⑥
13	Partial flooding	③④⑤⑥

Presence of solid material on tray # 12 may disturb liquid flow either through downcomer or down pipe. The location of the solid material on tray # 12 can be predicted by analyzing the density change of the scan data. Suppose that the cross-section of the column is divided into four quadrants as shown in Fig. 2. Scan on quadrants II and III did not shows any significant anomalies except for flooding on trays # 11 and # 12 only. Scan through quadrants I and IV, however, indicates very different features on which low and wide radiation intensity on tray # 12 was observed. This indicates that the solid material has grown on quadrant I and IV of the tray # 12. At the time of shutdown, two years after completion scanning work, it was found that the solid material on the tray #12 was a bucket buried in solidified mud, as shown in Fig. 9.

Presence of metallic bucket in down pipe of the tray # 12 is not expected to exist and it origin can be traced back to the time of last shutdown period when plant maintenance was carried out. Somebody put the bucket in the down pipe beyond the surveillance of project supervisor or plant engineers. This fact shows a carelessness of maintenance work during the shutdown time. Fortunately there was no fatal accident reported so far even after three years plant operation.

In engineering terminology the accumulation of unwanted deposits on the surface of plant constructions is usually referred to as fouling or deposit. When the size of the deposit is considerable as big as the occupied structure geometry, the deposit will embody as blockage. The accumulation of deposit (foulant) on the surface may result from a number of different mechanisms that are dependent upon the fluids being processed and the conditions plant operation such as temperature and velocity. The overall effect is that the equipment becomes less efficient in terms of heat transfer and may suffer from other problems of operation [16,17].

Fig. 9. Suspicious solidified material observed by gamma scanning was verified at the time of shutdown. A bucket buried in solidified mud was found on tray # 12 of DA-202 tower.

As can be seen from Fig. 9 (top-right), the deposit was dominated by particulate matter. Deposit material due to chemical reaction including corrosion is also observed as indicated by visibly metallic freak on top surface of the tray. Particulate deposit as mud may originate from feedwater containing mud particles. Metallic deposit on the other hand surely caused by plant operating conditions which including high pressure, high temperature and processing materials. Presence of such deposit including bucket on tray # 12 leading to reduce its efficiency.

To sum-up, it is clear that by measuring and analyzing density changes presented in scan data many parameters indicating column performance can be obtained. Each tray with fluidized materials and the vapor space tell us 'the story' of its operating status. Gamma scanning technique, in this case, seems to be the only diagnostic tool available that can be applied with confidence to obtain the true hydraulic behavior of the column performance. The results of the scan can be immediate discussed with process engineers so that appropriate remedial action should be taken as soon as possible to reduce production loss.

Learning from this experience, it is proved that 70 mCi ^{60}Co gamma emitter was enough to examine the column having diameter 4.2 m which is typical size of the column in industrial process plant. In fact, the radiation activity of the source used in this experiment is very low, down to 1,000 or less, compared to the technique mostly used in industrial radiography. The source holder was designed to fulfill radiological safety standard in order to ensure that received dose to the inspection team and plant personnel or the public do not exceed dose permissible limits as recommended by the International Commission on Radiological Protection (ICRP) [13]

CONCLUSION

Gamma scanning technique has been demonstrated for on-line diagnosing the performance of water wash tower DA 202 of ethylene plant in petrochemical industry. Scanning data shows that all trays were in their position. Tray # 4 to tray # 10 are carried approximately the same amount of liquid. Light flooding was observed on tray # 11. Heavy flooding in addition to suspicious solidified material was identified on tray # 12. Tray # 13 has experienced partial flooding. The problems have been verified at the time of shutdown and it has found that a bucket in solidified mud was found in down pipe of tray # 12. As it simple in operation and no column precondition are needed the gamma column scanning is very convenient to be applied in petrochemical plant.

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