CHEMICAL ENGINEERING TRANSACTIONS

VOL. 69, 2018

A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.aidic.it/cet

Guest Editors: Elisabetta Brunazzi, Eva Sorensen

ISBN 978-88-95608-66-2; **ISSN** 2283-9216

Results of Process Equipment Imaging by Tomographic Gamma Scan

Marcio I. Haraguchi[a*], Hae Yong Kim[b], Wilson A. P. Calvo[c]

[a]Tricom Tecnologia, Av. Conselheiro Rodrigues Alves, 58, Piquete, Brazil.
[b]Universidade de São Paulo, Escola Politécnica, Av. Prof. Luciano Gualberto, tr. 3, 158, São Paulo, SP, Brazil.
[c]Nuclear and Energy Research Institute – IPEN/CNEN-SP, Av. Prof. Lineu Prestes, 2242, São Paulo, SP, Brazil.
marcio@tricomtecnologia.com.br

Gamma scanning is a nuclear inspection technique widely used for troubleshooting industrial process equipments in refineries and petrochemicals. A radiation source and detector move vertically along the height of the vessel and the radiation readings are used to plot the graph of density profile. In recent years, many improvements have been added to this technique, but essentially the result of gamma scanning still consists of a 1-D density plot. Developed in 2012, the tomographic gamma scan uses image reconstruction techniques to show the result of gamma scan as a 2-D density distribution image. In this work, we present the current status of the technology and the results obtained by applying the technique to real operating process equipment. The results present images that match well with the 1-D density plots obtained by the conventional gamma scan and reveal process and operational problems that has never been visualized before with the traditional technique. The tomographic gamma scan can be immediately applied in practice with low financial investment.

1. Introduction

Distillation column density profiling or "column scanning" (Charlton, 1986) is commercially available for more than 30 years (Severance, 1981) and has been successfully applied in many countries around the world. Gamma scan results can be used for several purposes inside a plant such troubleshooting problems (Kister et al., 2017), operational and turnaround planning, and design studies (Outili, et al.,2013).

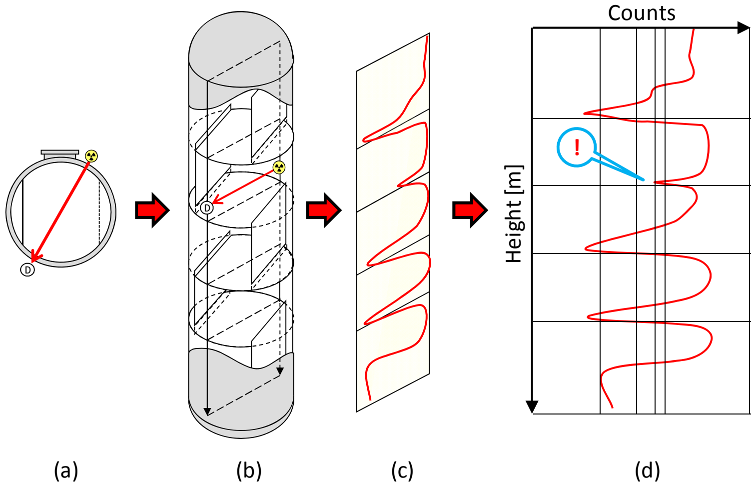

Figure 1: Typical gamma scanning process: job planning (a), field data acquisition (b), plotting (c), reporting and interpreting (d)

The main concept of the gamma scan is simple. It consists of a gamma source and radiation detector capable of moving to the same height with the aid of a positioning apparatus. An electronic interface for power supply and counting system is often connected to a computer for data storage and graphic plotting. A typical gamma scan job process is presented in Figure 1.

The results obtained are represented by one or more lines in XY plot with counts, or relative densities, on the abscissa axis and heights on the ordinate axis. Low count peaks represent high density areas and high count valleys represent low density areas. The density profiles represent the vessel, internals and hydraulic profile of the column, which correspond to the average radiation absorption at each height.

Over the years, this inspection service has incorporated advances such as portable computers, improved acquisition software, wireless detection, automatic positioning, data interpretation (Pless, 2014), etc. However the basic concept remains the same and the results still consist of a 1-dimensional density profile of the column. New technologies such as industrial tomography (IAEA, 2008) had been also introduced (Xu et al., 2009) and although became commonly applied in research works (Busciglioa, et al., 2017) there are still few cases in the Non Destructive Test (NDT) industry (Wolschlag et al., 2010).

2. Image improved gamma scans

In 2012, an innovative concept (Haraguchi et al., 2012) was proposed to obtain a 2-dimensional density profile of an industrial equipment at the same vertical plane as the regular gamma scans. This proposal was part of requirements for the Master of Science program at Center of Radiation Technology (CTR) of Institute for Nuclear and Energy Research (IPEN), Brazil. This technique, shown in Figure 2, resulted in a patent deposit and Petrobras Technology Prize 2013 (in Refining and Petrochemicals category, Master Degree) was granted to the inventors.

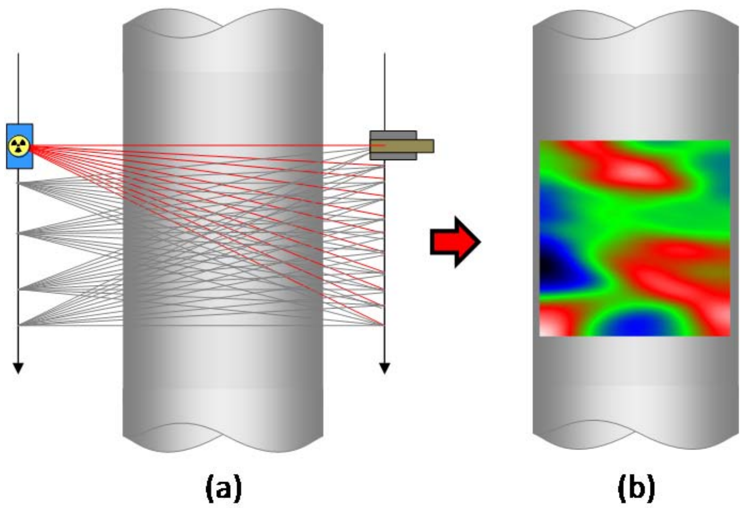

Figure 2: Tomographic Gamma Scan: Movement of source and detector and positioning scheme (a), sketch of an reconstructed image (b).

The concept was tested at CTR's laboratories with the irradiation of two column models designed to simulate situations difficult to be investigated with the regular gamma scan: a one-pass trayed column scanned perpendicularly through the downcomer area (Figure 3) and a random packing bed with empty areas, dense spots and unlevered packing simulating a severe liquid maldistribution (Figure 4). Image reconstructions were done in the Signal Processing Laboratory (LPS) of Escola Politécnica, Universidade de São Paulo. To facilitate visualization, we use pseudo-colors in the density distribution images with different colors representing different linear attenuation values. E.g.: black = air (μ = 68 × 10^{-6} cm^{-1}), green = water (μ = 63×10^{-3} cm^{-1}) and white = steel (μ = 420 × 10^{-3} cm^{-1}).

A 2-dimensional image of an industrial equipment represents an advance over the conventional gamma scan techniques, because:

- Dimensional – since conventional gamma scan registers only the mean density at each height, vertical features cannot be spatially localized. The tomographic scan overcomes this limitation by adding one more dimension. Equipments difficult to be inspected by conventional gamma scan (Urbanski et al., 1999) have now new possibilities of testing;

- Interpretation – internals, problems, process and phenomena are easier to understand in an image than in a conventional gamma scan plot.

As a secondary result of the project, other important capabilities were also developed:

- Irradiation simulation of the process and the internals of the equipment.
- A priori density distribution can be used to improve the results.
- The choice of reconstruction method and image filter to minimize errors (Kim et al., 2016).

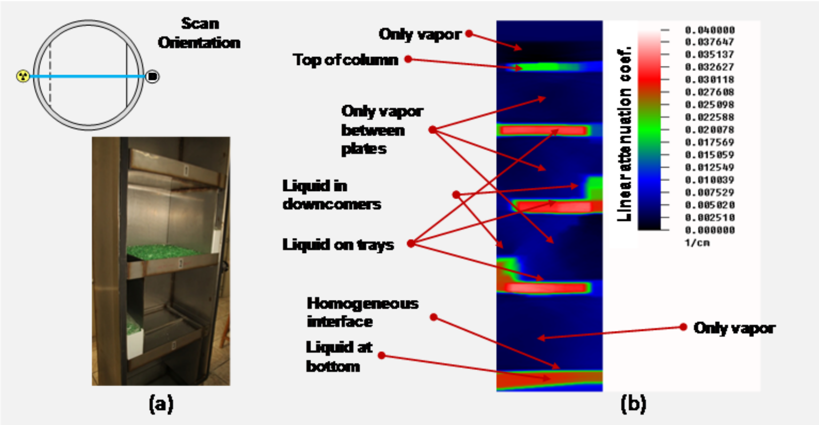

Figure 3: Trayed column model (a), image reconstructed after irradiation (b).

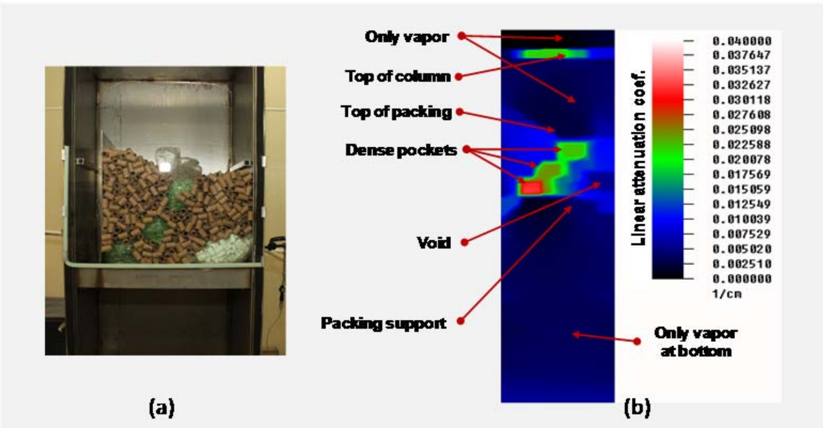

Figure 4: Packed column model (a), image reconstructed after irradiation (b).

3. Field testing

In 2014, a Ph.D. thesis was proposed with the objective to make the tomographic gamma scan available in real field conditions. The quest involved not only technology issues as reconstruction techniques and image quality, but considered other aspects involved on a typical field job such as scanning time; equipment characteristics (cost, weight, simplicity, robustness) and setup; and radiation safety into the decision matrix. A standard gamma scan equipment, with proper setup and minor modifications, was used to collect data of both cases presented in this paper.

3.1 Case 1 - Ripple Trayed Column

The first tomographic gamma scanning in a real industrial equipment was carried out in a water stripping column located in a petrochemical plant in Brazil. With 1,300 mm internal diameter and equipped with 10 ripple trays as shown in Figure 5, this column has been already scanned several times with conventional technique but results could not pinpoint any specific problem to explain the operational limitations. Only the top section of the column, including a 8” diameter fish bone type liquid distributor and 6 trays, was scanned with 10 cm spacing between consecutive positions of radiation source and detector, resulting in 908 data points collected in approximately 2 hours. The tomographic scans were performed in the same direction of previous conventional gamma scanning of this equipment to allow a direct comparison.

The result of the tomographic gamma scanning, shown in Figure 6, is consistent with the conventional scans. Imaging analysis should take into account the ideal operation of each internal and whether it contains, or not, liquid or aerated liquid. Any deviation from the ideal profile may indicate a mechanical or operational problem. The results of the analysis can be summarized as follows:

- The liquid distributor is in the correct place, with liquid and leveled. The scans crossed it diagonally and a symmetric shape can be seen at the corresponding elevation as expected, indicating that the central tube and lateral pipes are at their right places.
- An area of low density can be seen above the distributor, indicating that there is no liquid entrainment to the top of the column.

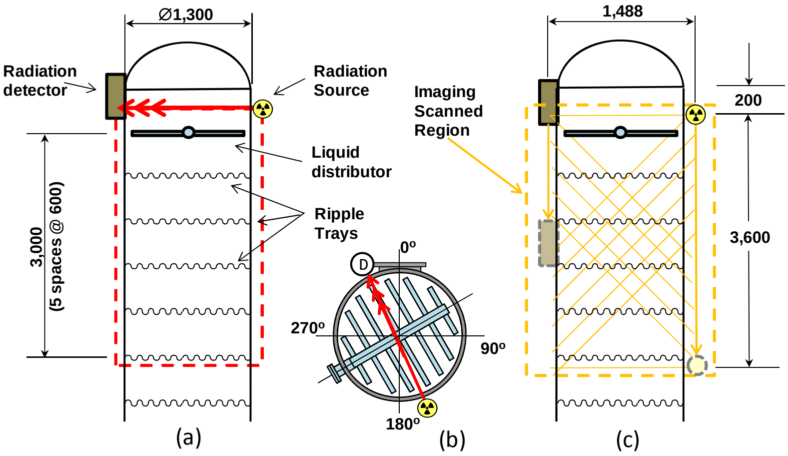

Figure 5: Top of water stripping column layout (a), conventional scan and imaging orientation (b), imaging scanned region (c).

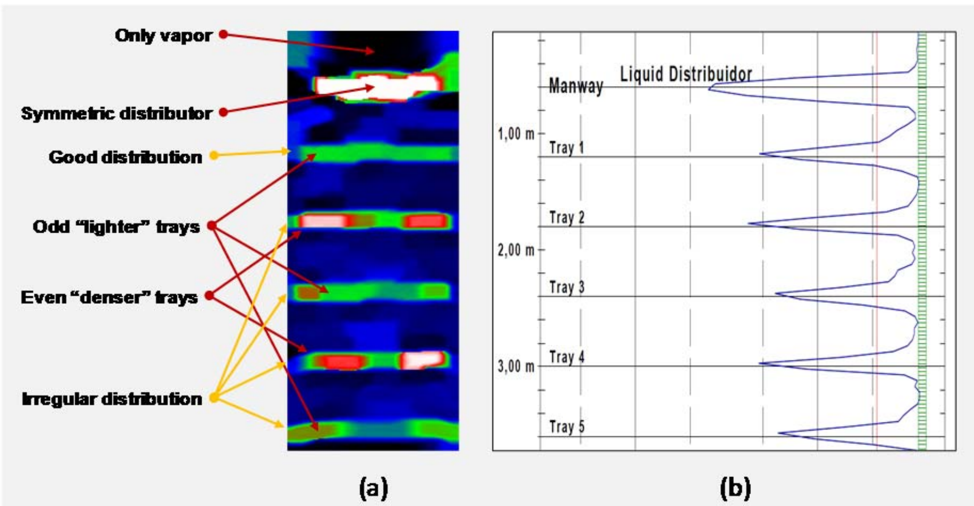

Figure 6: Imaging result (a), conventional gamma scan plot (b).

- Trays 1 through 5 can be seen at their appropriate elevations. The liquid in the trays seems to be leveled and there are no high densities in the spaces between trays that would indicate entrainment, flooding or other abnormal process phenomena.
- Even numbered ripple trays seem to be denser than odd numbered ones as indicated on both tomographic and conventional gamma scans. Ripple tray assembling explains the difference as even numbered trays are mounted 90 degrees shifted in relation to odd numbered trays. In fact, gamma rays cross even ripple trays transversely, hitting the metals of all tray ripples, while they pass almost parallel to the odd tray ripples, hitting mostly aerated liquid.

- The tomographic gamma scan seems to indicate a problem that has never been detected in any previous inspections of this column using conventional gamma scans: trays appear to be lighter at the center of the deck. Notice that tray number 1, right below the distributor, showed a homogeneous distribution. Maldistribution of liquid on the trays may cause this phenomenon, a problem that may occur in ripple trays probably due to different vapor velocities across the trays. Concentric maldistribution of liquid is very difficult to be detected with regular gamma scans.
- More tests (including industrial tomography) are being scheduled with the customer to further troubleshoot the column.

3.2 Case 2 - Deaerator

Traditional gamma scan plots are interpreted comparing the obtained density profile with the expected radiation attenuation resulting from the interaction of process with the internal parts. Internals that doesn't hold much liquid such as demisters, baffles, low liquid rate services, new and unusual-shaped equipments are difficult to troubleshoot with the conventional technique, because the scan profile can't be easily related to any problem or operational condition.

A 2,400 mm internal diameter deaerator of another petrochemical plant in Brazil, was experiencing poor performance with water being carried over though the vent nozzle. The vessel was scanned with 10 cm spacing between consecutive positions for radiation source and detector, resulting in 1,371 data points collected in approximately 3,5 hours. The tomographic scans were performed in the same position as the conventional gamma scanning of this equipment (red line) to allow a direct comparison.

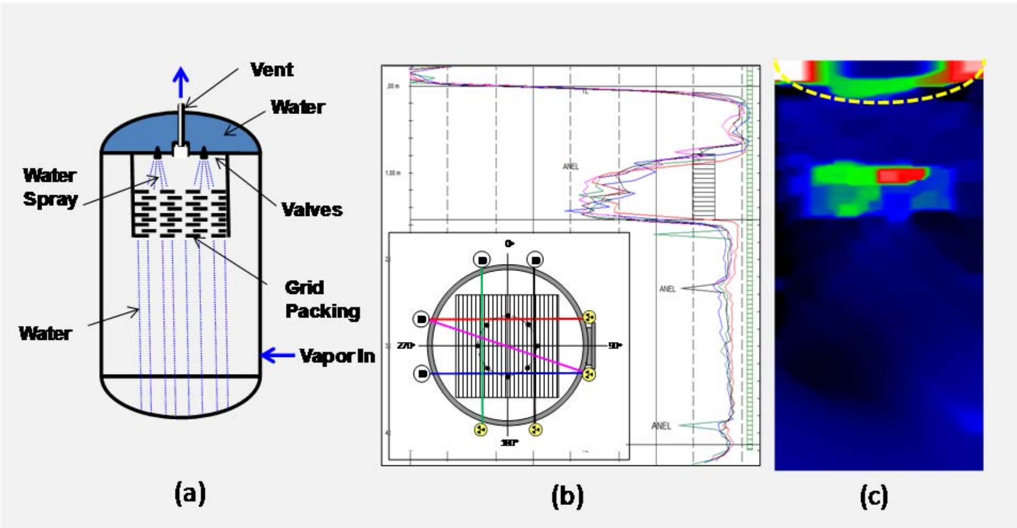

Figure 7: Desaerador sketch (a), conventional gamma scan orientation and plot (b), density profile obtained by tomographic gamma scan (c).

Regular gamma scans indicated no signs of flooding or excess entrainment. Although the grid packing doesn't show a consistent height and profile as it would be expected, not much more information could be gathered from the data. Imaging results match the findings of the gamma scans but also revealed more about the grid packing:

- Density distribution is very inconsistent at the grid packing, with a dense spot appearing at the top right (red zone), an intermediate density (probably liquid) on the left side (green region) and a low density region (probably dry grid packing) appearing just beneath the dense spot.
- It does appear that a dense and flat object is blocking the liquid flow at the top of the grid packing.
- The top and bottom limits (yellow dotted area) of the image have reconstruction limitations due to the lack of scanning data in this region.
- The imaging data doesn't reveal the origin of water being carries over with the vapor trough the vent.
- Customer decided to live with the problem until a shutdown opportunity arises.

4. Conclusion

The successfully experimental field tests on registering a theoretical phenomena and revealing an unpredictable equipment problem showed how the tomographic gamma scan opens a new field of opportunities for the research and industry in Non Destructive Test (NDT). In the short time, it would not compete directly with the conventional gamma scan but complement it. However, the cost-benefit may change as technology advances with multi detector systems and multi slice scanning. Another important achievement for the NDT industry is the use of conventional gamma scanning equipment for data sampling, allowing a fast transition to the new technology, with low financial impact.

References

Busciglio A., Opletal M., Moucha T., Montante G., Paglianti A., 2017, Measurement of gas hold-up distribution in stirred vessels equipped with pitched blade turbines by means of electrical resistance tomography, Chemical Engineering Transactions, 57, 1273-1278 DOI: 10.3303/CET1757213

Charlton J. S., 1986, Radioisotope Techniques for Problem Solving in Industrial Process Plants, Gulf Publishing Company, Houston, USA.

Haraguchi M. I., Kim H. Y., Sprenger F. E., Calvo W. A. P., 2012, Industrial Equipment Troubleshooting With Imaging Technique Improved Gamma-Ray Absorption Scans, Journal of Physical Science and Application 2 (9) 359-371, David Publishing.

International Atomic Energy Agency, 2008, IAEA-Tecdoc-1589 - Industrial Process Gamma Tomography. Final report of a coordinated research project (2003-2007). 3rd October, ISBN 978-92-0-104508-9.

Kim H. Y., Haraguchi M. I., Calvo W. A. P., 2016, Comparison of Industrial Tomography Algorithms for Gamma Scanning 2-D Reconstruction, WCIPT8 - 8th World Congress on Industrial Process Tomography, Iguaçu Falls, Brazil, ISBN: 978 0 853 16349 7

Kister H. Z., Winfield C., 2016, What Process Troubleshooters Should Know about Downcomer Gamma Scans, Presented at Distillation Topical Conference AIChE Spring Metting, April 10-14, Houston, USA.

Outili N., Chegga N., Elbahi K., Meniai A.H., 2013, Effect of Downcomers Sizes on Tray Column Performance, Chemical Engineering Transactions, 32, 1981-1986, DOI:10.3303/CET1332331

Pless L. T., 2014, Distillation Tower Gamma Scanning – Now a Quantitative Tool for Measuring Useful Capacity, 10th International Conference on Distillation & Absorption 2014, Friedrichshafen, Germany, 988-994.

Severance W. A. N., 1981, Advances In Radiation Scanning of Distillation Columns, Chemical Engineering Progress 77(9):38-41

Urbanski N. F., Resetarits M. R., Shakur M. S. M., Monkelbaan D. R., Bucior D. A., 1999, Gamma Scanning a Column Containing Closely Spaced Trays, Annual Meeting AIChE 1999, T1007c, Dallas, USA.

Wolschlag L. M., Couch K. A., 2010, Upgrade FCC Performance, Hydrocarbon Processing, September 2010, 57-65, Gulf Publishing Company, USA.

Xu S. X., Kennedy G., 1999, Gamma-Ray Computer-Aided Tomography of Industrial Packed Columns, AIChE 1999 Spring National Meeting, Houston, USA.