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Development of a scintillator detector system for γ-ray scan measurements of industrial distillation columns

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Abstract

A CsI(Tl) scintillator detector set was developed for γ-ray scan measurements aiming to identify process failures in distillation columns of an industrial petrochemical plant. A system with a ^{60}Co sealed source as a γ-ray emitter and the developed CsI(Tl) detector were applied to evaluate the performances in a simulated model of a tray-type distillation column.

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Keywords: Scintillator; γ-Scanning; Attenuation; Cesium iodide detector

1. Introduction

The distillation column is one of the most important parts of the petroleum refinery and chemical processing plants, separating the components of a liquid mixture, and the performance of this process determines the quality of the material being produced.

The γ-scanning technique is a fast, efficient and cost–effective tool for better understanding the dynamic processes taking place in industrial columns and examining inner details of a distillation process is in operation. This nondestructive technique provides an accurate density profile of an on-line process, and it can be applied to troubleshooting, debottlenecking, predictive maintenance and process optimization [1].

Nowadays, the detector often used to γ scan is built using a NaI(Tl) crystal coupled to a photomultiplier. However, for use as portable counters, some of their disadvantages are: (a) the need to operate at high voltage applied to the photomultiplier, (b) the sensitivity to the magnetic field and (c) mechanical shocks [2]. The use of the CsI (Tl) crystal coupled to PIN photodiode overcomes

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these limitations and the small dimension of the photodiode permits to project a heavy duty and compact detector at a low cost.

In this paper, a CsI(Tl) counter was developed and γ-scanning was performed in a simulated model of a tray-type distillation column using this CsI(Tl) detector. The γ-scanning was also carried out using the NaI(Tl) detector, for comparison.

2. Experimental methods

The portable counter was built using: (a) a detector of CsI(Tl) crystal coupled to Si PIN photodiodes (model S3590, Hamamatsu); (b) amplification units; (c) analogue-digital interface and (d) 60 m coaxial cables for signals transmission from the detector to the processing unit [2].

To develop the γ-scan system, a simulated model of a tray-type distillation column was built as showed in Fig. 1. Inside this column, a similar structure as found in the industrial systems was placed, with liquids of different densities in some levels of altitudes.

For the distillation column scanning, a ^{60}Co γ-ray sealed source and a radiation detector were moved simultaneously down the opposite sides of the column and measuring the radiation intensity .

The activities of the ^{60}Co source required were calculated by simulation software. In this software, the following parameters were considered: (a) the sensibility, (b) the detector type, (c) the statistic error, (d) the detector resolution, (e) the detector efficiency and (f) the measurement system geometry [1].

The scanning was carried out using as detector the developed CsI(Tl) detector and a commercial detector of NaI(Tl) 2 in. $\times$ 2 in. Minekin (model 9501). All counting values were obtained within a confidence level of about 95%. The counting time was fixed in 10 s, based on the work real conditions [3,4].

In order to determine the mass attenuated effective coefficients, the radiation attenuation intensity was measured previously, filling the column with liquids of known density values. The mass attenuated effective coefficients were calculated using the following relation: $\mu_{\text{eff}} = \ln(I_0/I)/(\rho x)$, where I_0 is γ-ray intensity in the empty column, that is, no medium interfering the transmission of the radiation; I is the intensity of radiation transmitted through different materials; ρ is the average density of the material inside the column; μ_{eff} is the effective mass absorption coefficient of the material and x is the thickness of the material (radiation path length). For γ-rays of energy greater than 200 keV, the mass absorption coefficient is nearly independent of the elemental composition [1].

So, as the μ_{eff} is a constant, the profile of the densities system was obtained plotting: ln(I) vs. column altitude, according to the equation: $\ln(I) = \ln(I_0) - \mu_{\text{eff}}\rho x$.

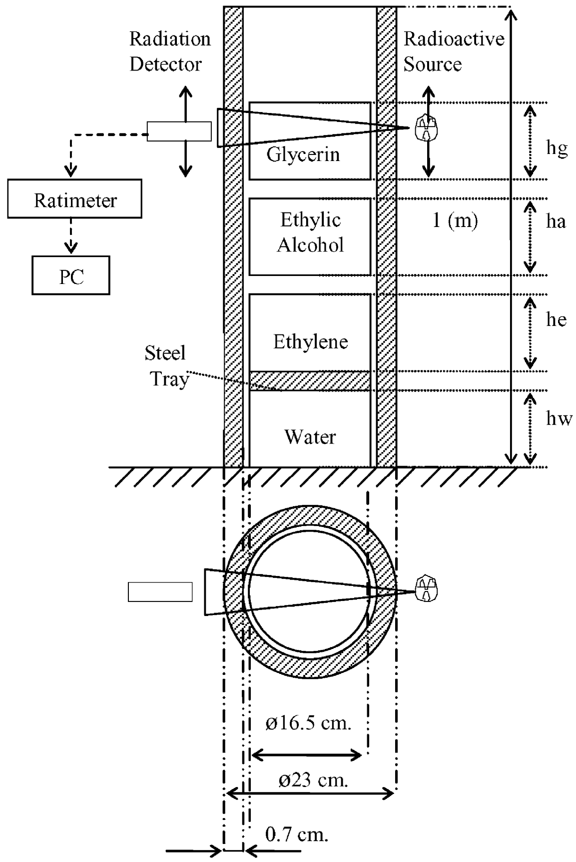

Fig. 1. Schematic diagram of the simulated model of a tray-type distillation column filled with different density liquids.

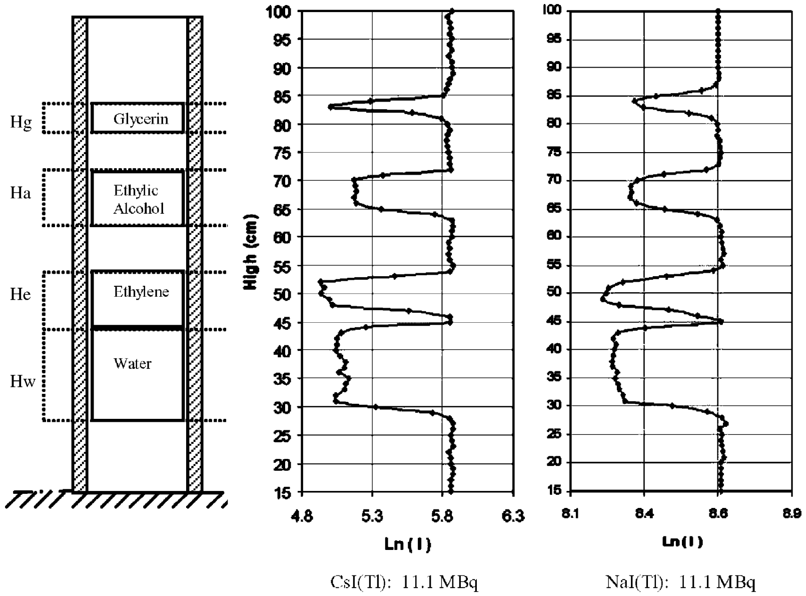

Fig. 2. γ-scans profiles of the simulated column.

3. Results and discussion

As can be observed in Fig. 2, both detectors, CsI(Tl) and NaI(Tl) presented similar profiles and the γ-scanning can detect and distinguish the small difference of the liquid densities. The statistical fluctuations for the CsI(Tl) detector were larger than those found for the NaI(Tl) detector, due to the lower efficiency (3%) of the CsI(Tl) compared to that of the NaI(Tl) (30%) (Table 1). However, the obtained efficiency value of 3% is good, considering the small volume of CsI(Tl) crystals of 2.5 cm^3, while the dimension of the NaI(Tl) is 81 cm^3. Nevertheless, the uncertainty values found for both detectors measurements are suitable for the proposed application.

Table 2 summarizes the results of the spray heights inside the column and the effective mass attenuation coefficient. The liquid level and its relative position were clearly distinguished. A good accuracy for the spray height results was obtained experimentally, for both detectors, as shown in Table 2. The mass effective attenuation coefficient (μ_{eff}) values obtained were significantly different for each liquid, as expected [1].

Fig. 3 shows the scan profile of a full column compared to that obtained in an empty column. In this figure, the influence of the metallic tray inside the column can be observed clearly. Jones-Jones and Severance [1] have demonstrated that the γ-scan in an empty column is essential to identify the interference and absorption caused by the column structure, providing a better resolution of the fluid hydraulic in the distillation process. In this work, the attenuation of the foam was not discriminated, probably due to the low density of the used material. However, the foams formed in the industrial distillation process present higher density, which should enable to distinguish their interference.

Table 1
γ-scans intensity results and the statistic errors

	CsI(Tl) detector	NaI(Tl) detector		
	Mean value (cps)	Statistic error (%)	Mean value (cps)	Statistic error (%)
I_0	355.29 ± 11.69	3.35	5500.9 ± 46.1	0.85
I	139.39 ± 7.34[a] 355.79 ± 11.70[b]	5.35[b]	3669.9 ± 37.8[a] 5569.7 ± 46.4[b]	1.04[b]

[a]Minimal values.
[b]Maximal values.

Table 2
Results of spray heights and effective mass attenuation coefficients

Spray height (cm)				Effective mass attenuation coefficient μ_{eff} (cm^2/g)	
	Liquid relative density	Real value	Experimental value	CsI(Tl) detector	NaI(Tl) detector
Hw	1.0	17.7	18.0 ± 0.3	0.0481 ± 0.0007	0.0221 ± 0.0004
He	1.12	9.5	10.0 ± 0.5	0.0490 ± 0.0006	0.0237 ± 0.0004
Ha	0.79	10.5	10.0 ± 0.5	0.0530 ± 0.0011	0.0186 ± 0.0004
Hg	1.26	5.5	5.0 ± 0.5	0.0415 ± 0.0005	0.0179 ± 0.0004

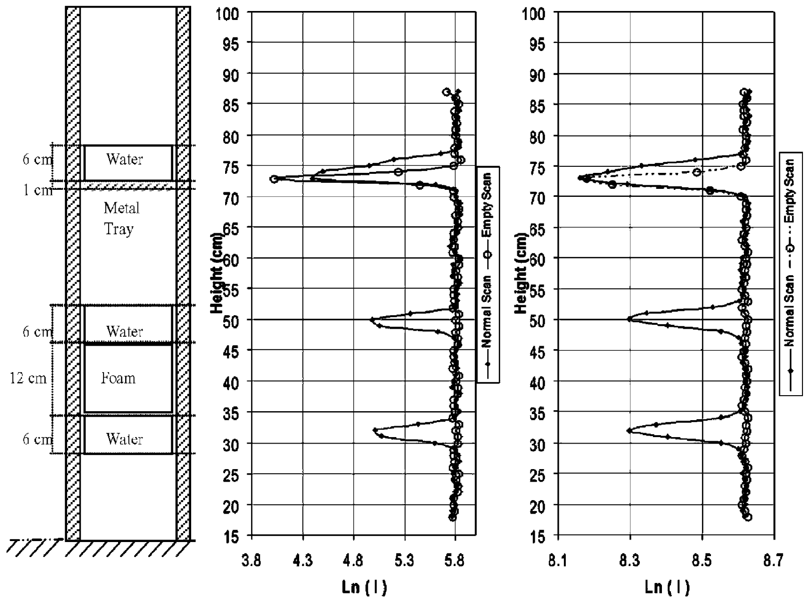

Fig. 3. γ-scan profiles of the normal scan (full column) and empty scan (empty column).

Concluding, the developed γ source-CsI(Tl) detector system showed to be suitable for the γ-scanning technique.

For a future work, the system test under a real industrial column will be carried out with a ^{60}Co panoramic irradiator and the same detectors. An activity of 1.11 TBq (30 mCi) has been calculated as a suitable required value.

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References

[1] J. Thyn, R. Zitny, J. Kluson, T. Cechak, Analysis and Diagnostics of Industrial Processes by Radiotraces and Radioisotope Sealed Sources. Vol. 2, CVUT, 2000.
[2] F.E. Costa, M.M. Hamada, Nucl. Instr. and Meth. A 353 (2002) 486.
[3] M.E. Harrison, Chem. Eng. Prog. 3 (1990) 86.
[4] J.D. Bowman, Chem. Eng. Prog. 9 (1993) 89.