International Journal of Innovation and Applied Studies
ISSN 2028-9324 Vol. 4 No. 2 Oct. 2013, pp. 408-412

http://www.issr-journals.org/ijias/

An Optimized Gamma-ray Densitometry Tool for Oil Products Determination

***Amirmohammad Beigzadeh*[1], *Hossein Afarideh*[1], *Eskandar Asadi Amirabadi*[2], *Zahra Soltani*[1], *and Gholam Reza Etaati*[1]**

[1]Energy Engineering and Physics Department,
Amir Kabir University of Technology,
Tehran, Iran

[2]Department of Physics,
Payam-e-Noor University,
Tehran, Iran

ABSTRACT: Gamma-ray densitometry or nucleonic gauges have been widely used in industries to improve the quality of products, optimize processes and save energy and materials. Compared with common time-consuming and expensive chemical analyses, the proposed method is relatively fast and more reliable. Density measurement is normally based on the absorption of gamma radiation as it passes through the process material. The absorption which is proportional to the changes in material density indicates product density as the measuring path is held constant. In this study, a number of Monte Carlo simulations have been performed using the MCNP-4C code to optimize the arrangement of gamma densitometer. The dimensions of the proposed system have been chosen to coincide with the industrial specimen of gamma densitometer. The geometry of source to detector in different angles was investigated and optimized angles were chosen. The simulation as well as experimentally measurements has been performed for 4 different fluids including water, gasoline and diesel engine oil used with iron and PVC pipes of 4 inches diameter. The gamma source and detector have been a ^{137}Cs and NaI(Tl) scintillation detector. Our experiments and simulations results show that the transmission mode present, better results than the scattering one in densitometer. The single detector response of the detector located at 180° can distinguish the gasoil, gasoline and water densities.
By optimized counting time and source-detector geometry, the densities of above mentioned fluids within the precision of 0.1 g/cm^3 were achieved.

KEYWORDS: Gamma-ray Densitometry, MCNP-4C, Oil Products, Measurements, scintillation detector.

1 INTRODUCTION

Simple nucleonic gauges (NCS) first began to be used in industry over forty years ago. Since then, there has been a continuous expansion in their usages. The competition from alternative methods shows that the nucleonic gauges have survived and prospered in the past because of their superiority in certain areas to conventional methods. The success of NCS is due primarily to the ability conferred by their unique properties, to collect data, which cannot be obtained by other investigative techniques [1].

Density measurement has found important applications in various industries, such as oil and gas productions, mining and mineral ore processing, environmental monitoring, paper and plastics industries, cement and civil engineering industries, where the benefit is enormous and the technology competes effectively with conventional techniques. The observed trends and new developments include the use of Monte Carlo simulations for design optimization, calibration and data processing [1], [2], [3].

There are basically three main categories of nucleonic gauges used in industry:

Corresponding Author: Amirmohammad Beigzadeh (beigzadeh_am@yahoo.com)

(1) Transmission gauges used to measure the density, thickness, etc. In these gauges the source housing and the detector are on opposite sides of the material and the radiation is attenuated as it travels through the material.

(2) Backscatter gauges used to measure the thickness of coatings, well logging, etc. Here, the detector and source housing are on the same side of the material and therefore the detector has to be shielded from the primary radiation. The radiation enters the material, interacts with it and scatters back out.

(3) Reactive gauges (e.g., used for elemental analysis). In these gauges, certain low-energy gamma and X-ray sources cause fluorescent X-ray emissions in the material being investigated [1]. In this paper, the optimum position of detector toward source has been determined using the Mont Carlo simulations, and then the corresponding experimental set-ups have been prepared to verify the simulation results.

2 METHODS

Density measurement is normally based on the absorption of gamma radiation as it passes through the process material. The absorption which is proportional to the changes in material density indicates product density as the measuring path is held constant.

With several detectors installed over the same pipe cross-section both transmitted and scattered radiation, the measurements can be performed in several positions. Basically, the energy of scattered photons depends on the scattering angle. Therefore, there is a relationship between the detected radiation energy/ intensity, and the distribution of oil and gas inside the pipe. A Monte Carlo simulation model has been developed and implemented in order to compare the accuracy of both transmitted and scattered photons over the pipe line.

3 RESULT AND DISSCUSION

3.1 SIMULATIONS VS. EXPERIMENTS

MCNP is a general purpose Monte Carlo code for calculating the time-dependent, continuous energy, neutrons, photons and electron transports in three dimensional geometries [4]. A number of benchmark studies have been published using the Monte Carlo transport code, MCNP [5], [6]. Here, two simulation models according to the nucleonic gauges including the transmitted and back scattered ones, have been developed to measure the density of fluids as shown in Figure 1. It seems necessary to develop a model for the simulated one to locate the detectors, on the basis of the sensitivity of densitometer. In the case of water, gasoil and gasoline, 11 simulations have been performed, in which the detector angle ranges from 40 to 180 around the pipe with a 0.5 mCi ^{137}Cs gamma source. The choice of the gamma-ray source depends on the characteristics of the experiment such as the pipe material, pipes body thickness, diameter, detection sensitivity, and shielding considerations. The 662 keV gamma-rays from the ^{137}Cs source easily pass through the pipe wall materials, and therefore the uncertainties due to the counting statistics can be reduced. The densities of typical water, gasoil and gasoline at 30 °C under laboratory conditions are 0.920, 0.720 and 0.820 g/cm^3, respectively.

The tally F8 of the MCNP code has been considered as the detector pulse-height equivalent and hundreds of millions of computer runs have been performed for source particles. The final experiments setups were found to be consistent with the obtained results at simulation.

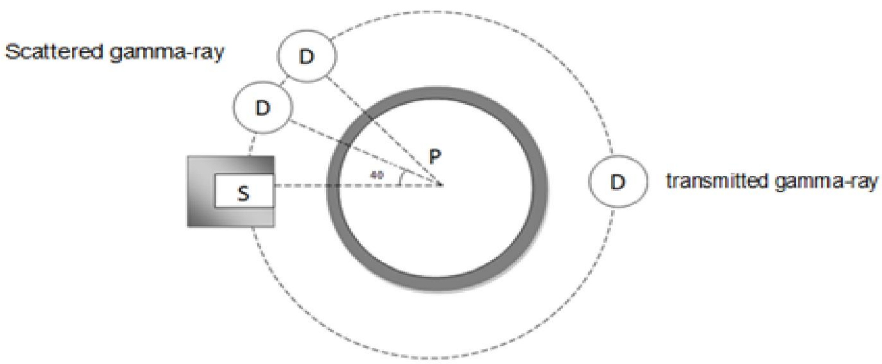

Fig. 1. Different configuration setups of density measurement system.

Figs. 2 and 3 show the detector count rates for several positions around the pipe for both scattering and transmission measurements for PVC and iron pipes, respectively.

As it can be seen, when the detector is located at the 3 specific angles (150,170,180 degrees), the highest count rates are obtained a procedure which determines the optimum detector position. The average counts for the detector located at 40°, 60°, 80°, 90°, 110° and 130° represent very small values only concerning the scattered photons detected in these angles. Therefore, the transmitted method has more sensitivity than the scattered one that means the transmitted-based gauges can determine and control the material density in the pipe more accurately.

The single detector response of the detector located at 180° can distinguish the gasoil, gasoline and water densities with the accuracy of 0.1 g/cm^3.

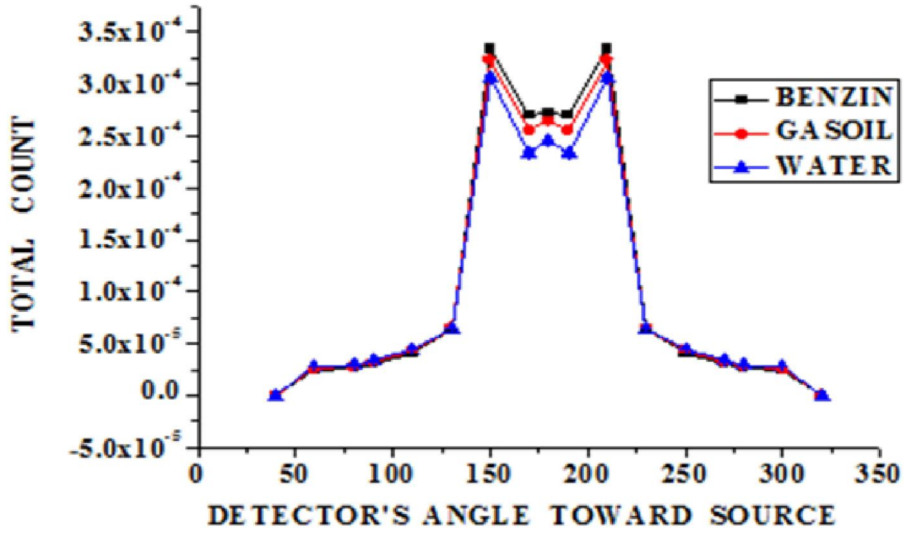

Fig. 2. Count rate vs. detector angle for iron pipe (MCNP simulation)

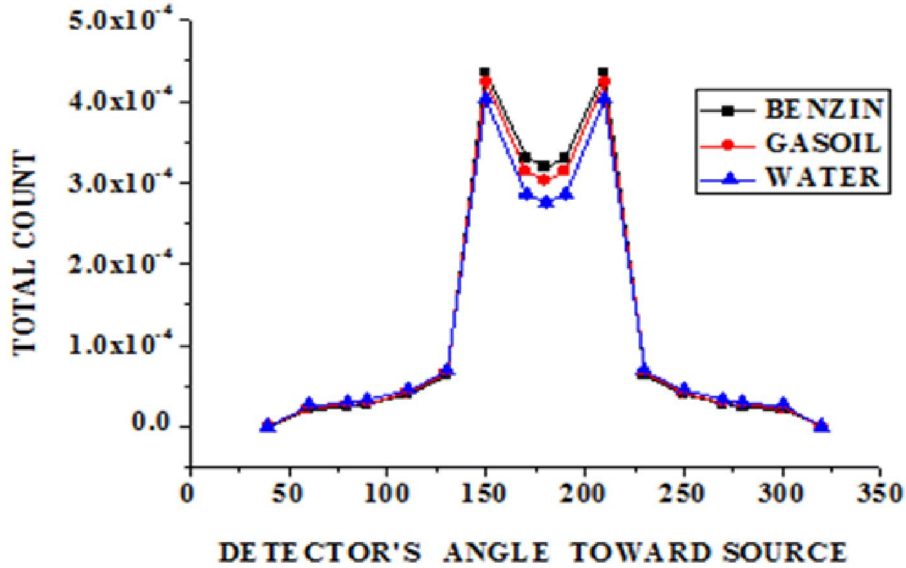

Fig. 3. Count rate vs. detector angle for PVC pipe (MCNP simulation)

Furthermore, as it can be seen in Figs. 4 and 5, the agreement between the experimental and simulation results is excellent. A small difference between the two curves may be partly corresponded to (1) the fact that the detector has not been fully simulated, (2) the background count rate variations and also (3) the environmental conditions. However, one may conclude that the MCNP code is an efficient tool for the simulation of nuclear gauging instruments.

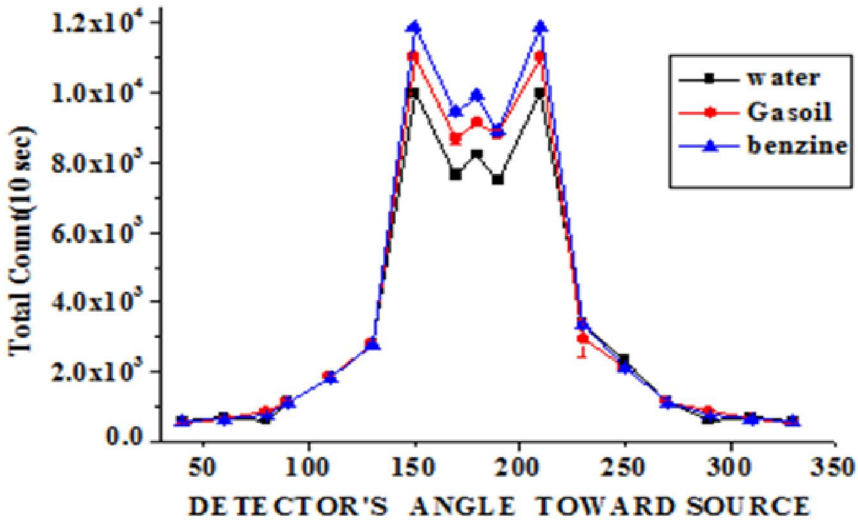

Fig. 4. Count rate versus detector angle for iron pipe (Experiment)

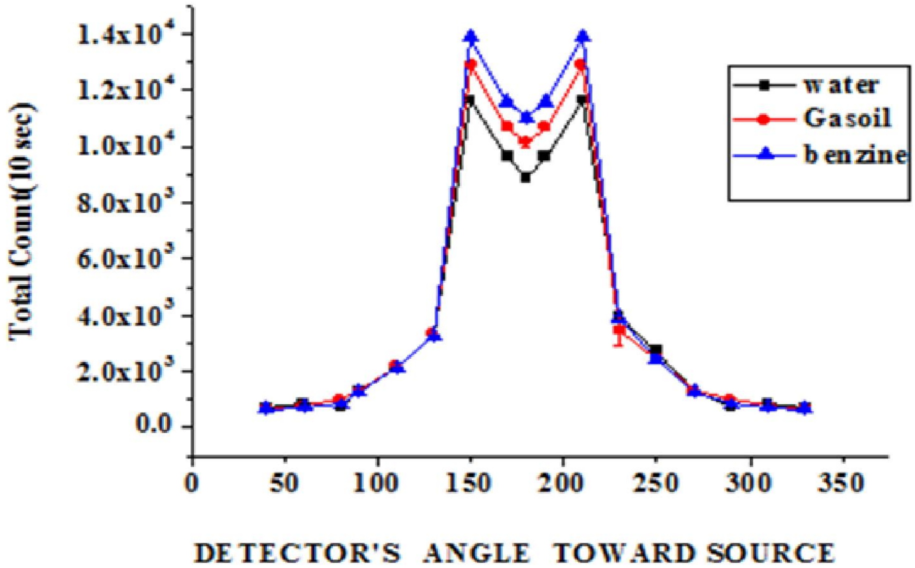

Fig. 5. Count rate versus detector angle for PVC pipe (Experiment)

Straight angle as the optimum detector position was selected for designing and setting up experiment. the experiment and simulations were performed for gasoil pipe using mentioned densitometer.

4 CONCLUSION

Our experiments and simulations results show that the transmission mode present, better results than the scattering one in densitometer. Based on the both MCNP4C code simulation and our experimental results, fluid densitometer device can be developed for industrial applications to distinguish the material with similar densities from one another with the accuracy of 0.1 g/cm^3

REFERENCES

[1] International Atomic Energy Agency (IAEA), *Technical data on nucleonic gauges*, IAEA Publications, IAEA-TECDOC-1459, July 2005.

[2] G.A. Johansen, P. Jackson, *Radioisotope Gauges For Industrial Process Measurements*, John Wiley & Sons, West Sussex, England, 2004.

[3] M. Maucec and I. Denijs, "Development and calibration of a gamma-ray density meter for sediment-like materials," *Applied Radiation and Isotopes*, vol. 67, pp. 1829–1836, 2009.

[4] J. F. Briesmeister, *MCNP Monte Carlo N-Particle Transport Code System*, Los Alamos, National Laboratory, 2002.

[5] M. Sohrabpour, M. Hassanzadeh, M. Shahriari and M. Sharifzadeh, "Gamma irradiator dose mapping simulation using the MCNP code and benchmarking with dosimetry," *Applied Radiation and Isotopes*, vol. 57, pp. 537–542, 2002.

[6] M. Sohrabpour, M. Shahriari, V. Zarifan, K.K. Moghadam, "Borehole prompt gamma neutron activation and comparison with Monte Carlo simulation using MCNP code: Borehole PGNAA experiment comparison with MCNP," *Applied Radiation and Isotopes*, vol. 50, pp. 805–810, 1999.