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A new automated and precise calibration method for gamma level gauges with rod detector arrangement

Reza Gholipour Peyvandi [a], Ali Taheri [a,*], Ali Olfateh [a], Seyyedeh Zahra Islami [a,b]

[a] Nuclear Science and Technology Research Institute, Tehran, Iran
[b] Department of Physics, Faculty of Science, University of Qom, Qom, Iran

HIGHLIGHTS

- A new calibration method was proposed for gamma liquid level gauges.
- The method is applicable in vessels or reactors with thick walls.
- There is no need to gain access to the inside of the vessel during calibration.
- Using this method, a level gauge can be calibrated automatically.
- The ability of the proposed method is shown using Monte Carlo simulation and experiments.

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ABSTRACT

Gamma-ray liquid level gauging is of particular importance in several industries. Industrial vessels, tanks, and reactors, which work at high temperatures and pressures, usually have thick metal walls up to 20 cm. These factors make it impossible to know the exact level of liquid or fluid while the system is operating. For this reason, the calibration process of the gamma level gauges is difficult as it is impossible to gain access to the inside of the vessels, which is important during the calibration process. In this study, a new auto-calibration method was proposed for the aforementioned situations.

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1. Introduction

The level measurement inside vessels or reactors in a plant is of particular importance because it leads to a more accurate assessment of different operations and consequently increasing the system performance. In addition, the source of process malfunctions can be identified using the level measurement. Another advantage of such measurements is simplification of many process operations. The level measurement is often carried out using gamma ray gauges. In a gamma ray gauge, a gamma source which its activity and energy are determined considering the vessel characteristics namely dimension, wall thickness and material etc. is placed on one side or inside the vessel and a gamma ray detector is placed on the opposite side (Johansen and Jackson, 2004; van de Kemp, 1993; Hjertaker and Johansen, 2001; Priyada et al., 2012). Source and detector can have different configurations: a point source and point detector which move together, a moving point source and a fixed rod detector or vice versa, and a rod source and rod detector that are both fixed. It is notable that in each of these configurations, the source can be placed inside the vessel (IAEA-TECDOC-1459; Gardner and Ely, 1968; Gardner, 1998). The difference in ρx between the two phases in the vessel is large in most systems encountered, and the position of the interface is thus indicated by a large change in the transmitted intensity recorded by the detector. The technique is rapid, versatile, and accurate (better than ± 2 cm in most cases). Because all equipment is external to the vessel, the measurement is applicable to any process material and is not impaired by conditions of high temperature, high pressure, or the presence of corrosive, viscous, or toxic materials. The technique has been used on vessels of diameter varying from a few centimeters to 10 m or more and with wall thickness of up to 20 cm of steel. The dimensions of the vessels favor the use of gamma radiation over other methods using radar or ultrasonic waves. Conversely, in large vessels with thick

* Corresponding author.
E-mail address: at1361@aut.ac.ir (A. Taheri).

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walls, calibration of these systems is difficult because there is no access to the vessel to see and measure the liquid level. In such circumstances, there are two common methods for calibration, calculation and measurement of the calibration curve, where the latter is the problem. In this study, we proposed a new method for automatic calibration of rod detector-based gauges. Using this method, there is no need to gain access to the inside of the tank for the calibration, and system will be self-calibrating. This study consisted of two steps: a Monte Carlo simulation and experimental tests.

2. Materials and methods

2.1. Monte Carlo simulation

A complete simulation of the level gauge and calibration method was done using MCNP4c code (Briesmeister, 2000) before the construction of the experimental setup.

A steel cylindrical shell with radius and height of 1.5 and 4 m, respectively, and wall thickness of approximately 17 cm was simulated as the vessel. In general, for measuring liquid levels in such a thick vessel, a gamma-ray source should be placed in it, without which the gamma photons will not be able to pass through the vessel. For this reason, a smaller cylindrical shell with radius, height, and wall thickness of 2 cm, 3.5 m, and 1 cm, respectively, was placed inside the vessel. A ^{60}Co rod-shaped gamma source with a height and activity of 1.5 m and 170 mCi, respectively, was placed inside this smaller cylinder. The distance between the axes of the vessel and source holder was 70 cm.

Three rod-shaped plastic scintillator detectors with lengths of 50 cm were placed outside of the vessel. These detectors were considered attached together and their axes were parallel to the vessel axis. This indicates that the distances between the centers of the detectors and the vessel bottom were 25, 75, and 125 cm for Rods 3, 2, and 1, respectively. A schematic of the simulated vessel and level gauge system is shown in Fig. 1.

The vessel was filled with urea $CO(NH_2)_2$ with a density of 1.025 g/cm^3. It is obvious that an increase of the height of the liquid inside the vessel affects the count rate of all three detectors.

It is important to note that in a real situation, the operator cannot see inside the vessel to find the liquid surface, which makes the calibration of the system difficult. In order to

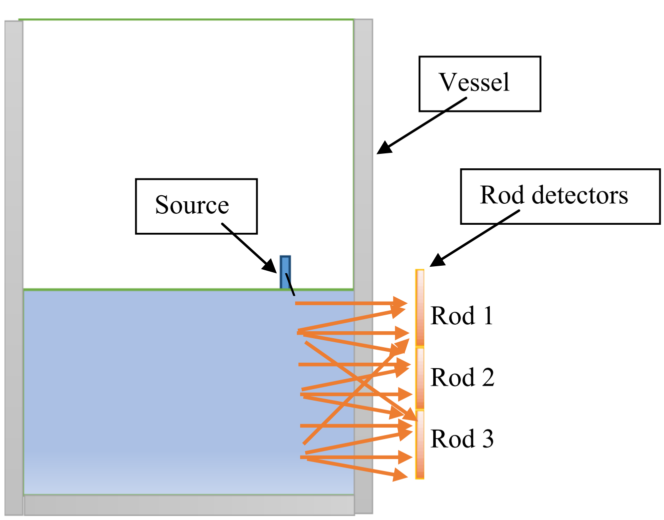

Fig. 1. Schematic of the simulated vessel and level gauge system.

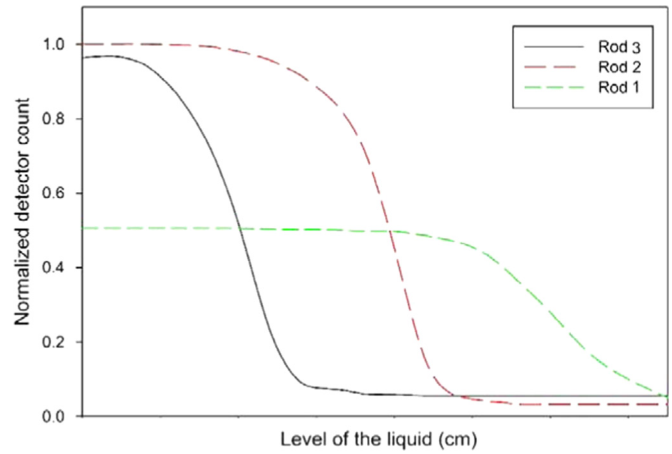

Fig. 2. Variation of the normalized detector count with the level of liquid.

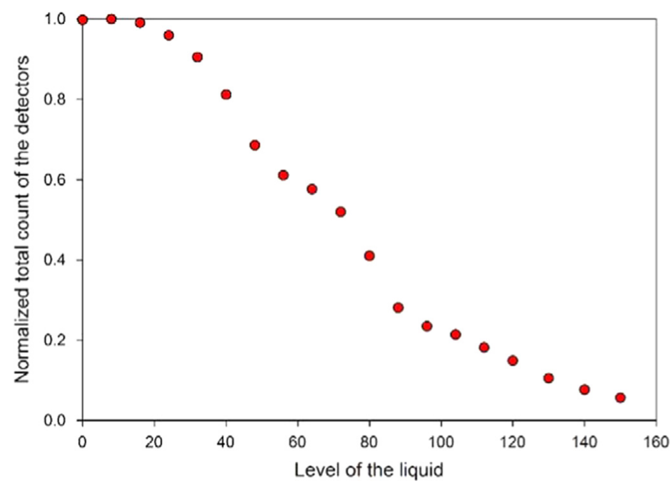

Fig. 3. Normalized total count of the detectors versus the level of liquid.

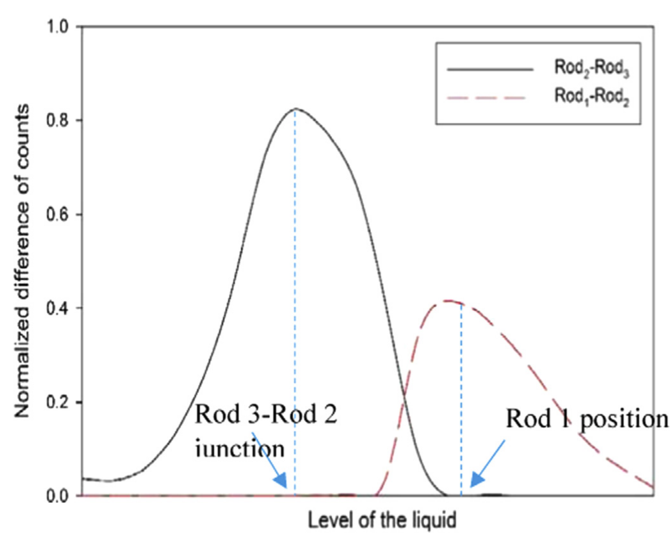

Fig. 4. Subtracted detector counts (shown in Fig. 2) as a function of the level of liquid.

estimate the detector response, Tally F6 was used to calculate the absorption of energy in the rod scintillator. For this purpose, the height of the liquid in the vessel was changed from 0 to 150 cm with a step of 10 cm.

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