

Design of a Nuclear Level Switch using MCNP code, and comparison with experimental results

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Nuclear level switches have found widespread use in industry, as they allow rapid and reliable on-line measurement and control of material level in the tanks and vessels. The nuclear level switch is based on the detection of radiations emitted by a radioactive source. When radiation transmit through material it will be absorbed, scattered or transmitted without any reaction. In view of the complexity associated with these interactions, the Monte Carlo simulation can be used for evaluation of radiation interactions with matter. In this work, the simulations were performed using the MCNP4C code. The system includes a ^{137}Cs gamma source, a water tank and a gamma detector. The count rate versus material level was obtained in the different positions of source and detector and the optimal conditions were determined for having the best sensitivity of gauge. An experimental work was also carried out to test the simulation predictions and a good agreement was found between experimental and simulation results.

INTODUCTION

Level height is an important feature in several pieces of technological apparatus, in material storing transportation systems, both from process control, either automatic or manual, and from quantity monitoring considerations. For monitoring the material level in a given system, level height indicators are used. The level indicator is suitable for sensing and remotely indicating a specified extreme value (minimum, maximum, etc.). It can be used as control elements, typically as process sensors [1].

There are several methods for detecting level material in tanks like: float, thermal level sensor, capacitance level detection, optical level devices, vibrating level switches, microwave level switches, radar sensors, ultrasonic level detectors, and radiation level sensors [2].

Unlike most other level technologies, the nuclear level switch can be considered as the most universal one because nuclear gauges avoid contact with process conditions. Processes with extreme temperature, pressure, or corrosive properties have no adverse effects on nuclear gauges. Nuclear level switch can be applied in closed and open systems. They can detect level of material in different states (solid, liquid, particulate, etc).

Nuclear level switch can be applied in virtually any industries such as: petrochemical, water and wastewater, pulp and paper, plastics, food, cement, asphalt, chemical and mining [3].

Material and Methods

A nuclear level switch contains a shielded radioactive source as a signal source and a detector converting radioactive radiation to electrical pulses. It can work based on absorption or reflection

of radiations. Absorption gauge is designed to measure the level of process material by directing a beam of gamma radiation energy from source, through the process material to a detector assembly on the other side. Some of this energy is absorbed during the passage through the material. This absorption is proportional to the mass of the material which it passes. The amount of radiation energy which reaches the detector is measured.

In reflection gauges, both source and detector are installed one side of the tank. If no material appears in sensing zone of probes, the reflection is low, due to interaction restricted to protective cover of the probe or the tank wall. With rising material level, the reflection increases significantly.

The sensitivity of gauge depends on radioisotope type as radiation source and its activity, detector type and the positions of source and detector. In this work, the proper position of source and detector was determined by simulation of nuclear level switch [4].

A proper location of source and detector should be determined in a way that to have high level indication accuracy for the level switch. More sensitivity can be achieved if the slope of the radiation count versus the level of material curve is higher. It means the detector should have a noticeable change in radiation count when the level of material is slightly changed. The MCNP transport code based on the Monte Carlo method has been used to simulate the nuclear level switch.

MCNP simulation

MCNP is a general purpose Monte Carlo code for calculating the time dependent continuous energy, transport of neutrons, photons and electrons in three dimensional geometries [5]. A number of benchmark studies using the Monte Carlo transport code, MCNP, and comparison with experimental results have been done [6,7].

The calculation model included a polyethylene tank of 80 cm diameter filled with water, a ^{137}Cs gamma ray source with lead shield and a gamma-ray detector. Fig .1 shows four different positions of source and detector that were simulated.

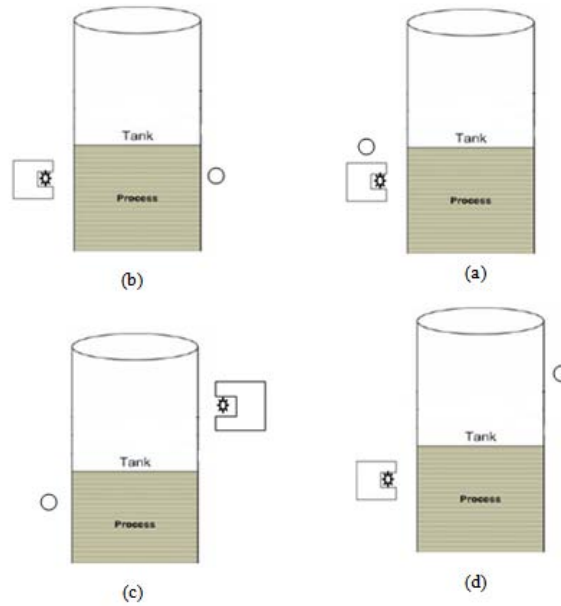


Fig. 1. The position of source and detector in four different situations

The count rate of the detector versus water level variations was determined. The numbers of histories were 5 million photons.

Experimental

A 100 mCi ^{137}Cs gamma source with lead shield is placed at level of 60 cm from tank bottom in situation (a) and (c), and at level of 35 cm in situation (b) and (d). A ZP1201 Geiger-Muller tube is used to count transmitted photons and a polyethylene tank of 80 cm diameter and 120 cm height have been utilized [8]. Water has been used as the material in the tank.

The set up of electronic unit's configuration for this experiment is shown in Fig. 2.

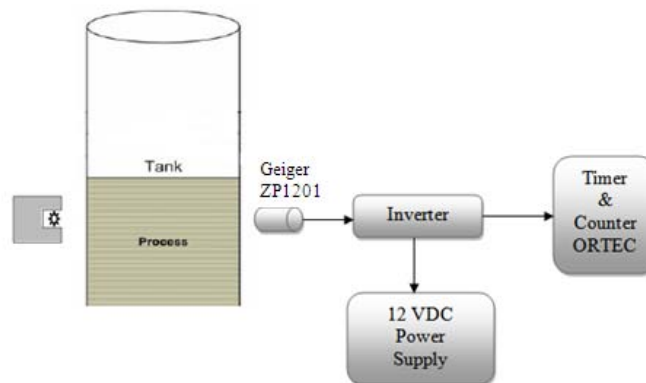


Fig.2 Configuration of electronics used in the experiments

Source and detector were mounted in the four positions. With raising the water level, in each level, the count rate in the detector has been counted 25 times in 5 seconds time intervals, and then averaged among the counts.

The simulation and experimental results

The following figures show the simulated count rate in the detector and the experimental results as function of water level in four positions.

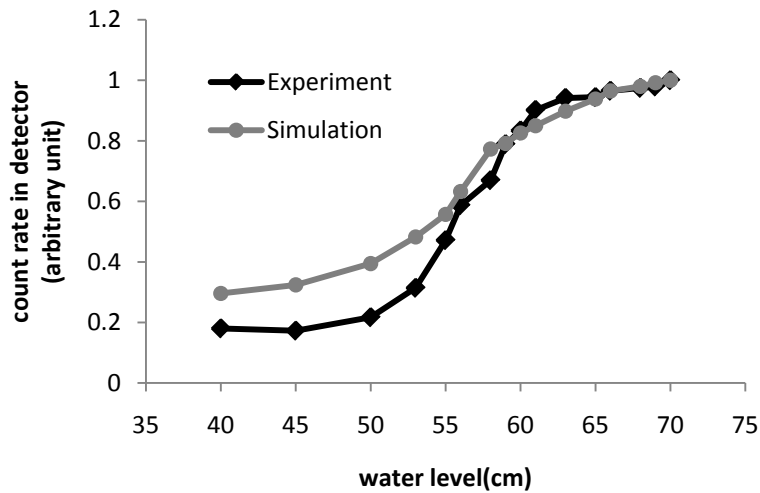


Fig. 3. Count rate of detector versus water height for situation (a)

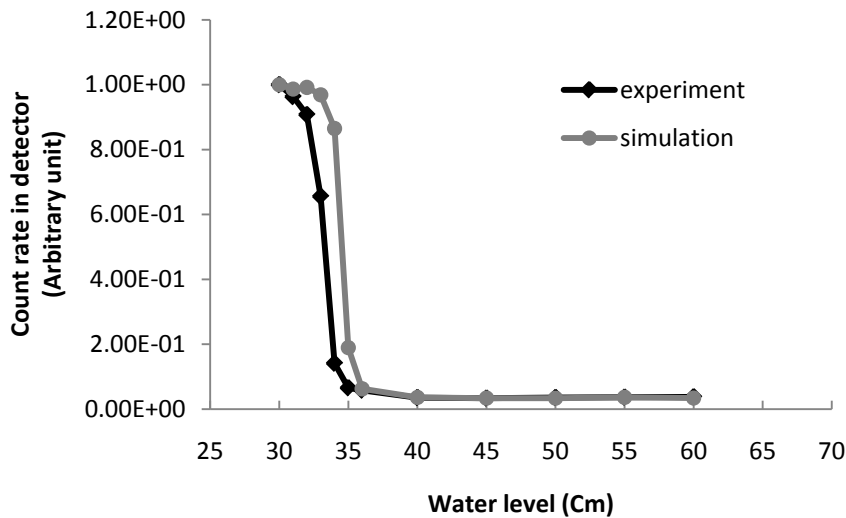


Fig. 4. Count rate of detector versus water height for situation (b)

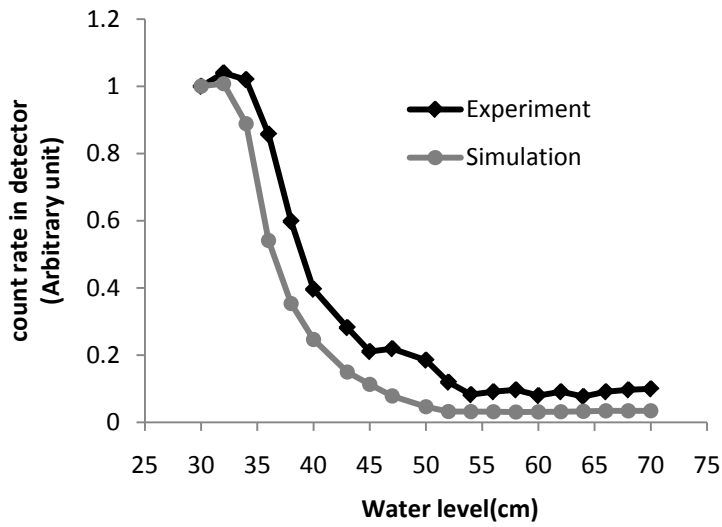


Fig. 5. Count rate of detector versus water height for situation (c)

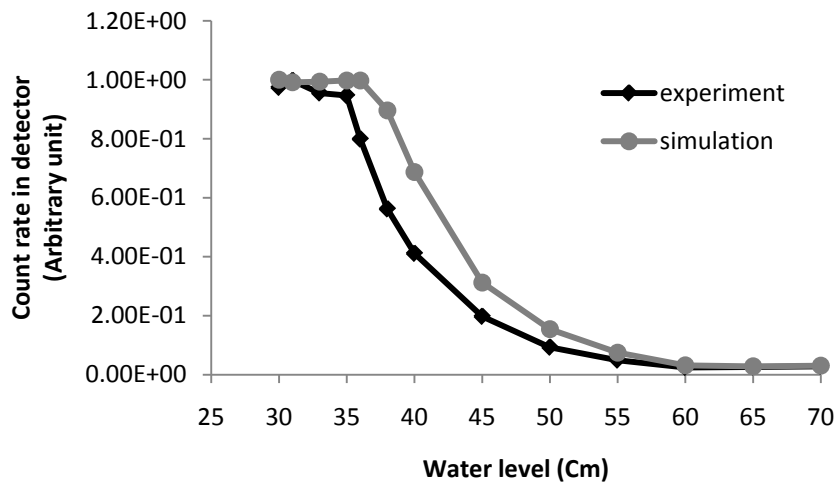


Fig. 6. Count rate of detector versus water height for situation (d)

Discussion

The comparison of the results of Fig. 2 with the others shows the absorption method has more sensitivity than reflection method and absorption gauges can determine and control the material level in the tank accurately.

However when we are not able to access two sides of the tank for the operational conditions or there is small amount of transmission radiation due to the large diameter of the tank, the use of reflection method appears to be inventible.

As can be seen in Fig. 4, the slope of the curve is higher than others and it is better the source and detector are mounted opposite each other in the specified height.

Also in situations (c) and (d) the gauge can determine material level continuously and it is possible to determine material level in the range of 35 to 55 cm with measuring count rate. In comparison, situation (c) is more suitable.

Furthermore, the agreement between experimental and simulated results is excellent; a small difference between the two curves may also be partially resulting from the impossibility of the exact simulation of the detector, background count rate variations and also environmental conditions. However based on the above conclusion, MCNP code is an effective tool for simulation of nuclear gauging instruments.

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