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Neutron backscatter gauge for bottom plate gap detection of storage tanks

A. S. Pendharkar, P. B. Walinjkar, S. S. Datta, Umesh Kumar, G. C. Das, Gursharan Singh

Email: aspen@apsara.barc.ernet.in

Isotope Applications Division,
BARC, Mumbai – 400085

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Isotope Applications Division, BARC, Mumbai – 400085
aspen@apsara.barc.ernet.in

Abstract

In the petroleum, chemical and petrochemical processing plants, gigantic storage tanks are used for temporary storage of crude oil, petroleum products, chemicals etc. Since the bottom plate of the tanks are subjected to tremendous stress due to the loading and off-loading activities, gaps may develop between the bottom plate and the foundation, which in turn can easily generate and spread cracks. Fast neutrons, in the range 0.5-11 Me V, lose their energy by scattering process. The concentration of thermal neutrons near the fast-neutron source is increased by the presence of hydrogen in the medium. The laboratory studies were carried out using the neutron backscatter gauge (Ludlum make) to detect the gap between the concrete and the metal sheet. It is observed that there is definite relationship between gap in foundation and slow- neutron count rate. Thus neutron backscatter gauge can be use to measure the gap in bottom plate of storage tanks used in the petrochemical industries.

Introduction

In the petroleum, chemical and petrochemical processing plants, huge storage tanks are used for temporary storage of crude oil, petroleum products etc. The reliability of these storage tanks is an important safety aspect. Problems such as sagging and irregular or localized sinking are normally encountered in high capacity storage tanks, especially if located on soft ground near the sea-shore. Since the bottom plate of the tanks are subjected to tremendous stress due to the loading and off-loading activities, gaps may develop between the bottom plate and the foundation, which in turn can easily generate and spread cracks. This will eventually lead to leakages, hence financial losses, and possible fire hazards. Therefore, to ensure safety, storage tanks are regularly emptied for various inspections covering both the tank itself and its foundation.

A neutron backscatter technique can be an alternative *non- destructive* method to the *hit and drill* method, which is not only destructive but also unreliable and time-consuming. The technique can be used for the measurement of the gap between the bottom plate and the base foundation and for detection of the presence of water or leakage of oil beneath the bottom plate of the tanks. The data obtained by the measurements enables the maintenance engineers to decide whether to repair the base foundation or continue using the tanks without any repair.

Principle

Neutrons emitted from radioisotope sources are energetic particles, with energies up to several MeV, such energetic neutrons are referred to as 'fast neutrons'. Fast neutrons; do not interact with the electric fields of atoms and molecules. In addition, because of the large mass of the neutron compared with that of the electron, neutrons are irrelevantly affected by electron collision. The only way in which a fast neutron passing through matter can lose its energy is by direct collision with an atomic nucleus. Therefore, fast neutrons are penetrating particles, capable of passing through substantial thickness of material and hence ideal for the tank floor scanning.

Fast neutrons, in the range 0.5-11 Me V, lose their energy by scattering process. In elastic scattering, the neutron is slowed down in the collision and its direction of motion is changed. In the energy range 30eV-0.5 MeV, elastic scattering is essentially the only process by which a neutron can be slowed down.

If the neutron energy before collision is denoted by E_1 and after collision by $E_{2,}$ it is possible to show that in a head-on collision, the energy transferred to the nucleus of an atom is

$$E_2/E_1 = [\ (A-1)/(A+1)]^2$$

Where A is mass number of the nucleus.

It is clear from the above equation that it is possible for a nucleus to lose all of its kinetic energy in a head-on collision with a hydrogen nucleus. Hence, the presence of hydrogen is a major factor in the slowing down of fast neutrons. The concentration of thermal neutrons near the fast-neutron source is increased by the presence of hydrogen. It also increased by the presence of non-absorbing elements, which hinder the motion of the neutrons. The higher the concentration of these elements, the shorter are the distances migrated by the thermal neutrons and the higher is their density near the source. This can be used to detect the presence of water or leakage of oil beneath the bottom plate of the tanks and is the basic principle of gap detection.

Experimental

The studies were carried out with the neutron backscatter gauge (Ludlum make). The gauge consists of ^{241}Am/Be (Americium-241/beryllium) neutron source and a He3 neutron detector that are housed together in thin-walled stainless steel housing and a count rate meter. The experimental arrangement is shown in Figure 1. It consists of a concrete slab of 1500 x 2000 mm with the slope angle of 15 degree was selected. A mild steel plate of 1000 x 1500 mm having thickness 4mm was placed by keeping a 110 mm diameter pipe having 4mm wall thickness at the one end. Five sets of measurements are taken at five different locations marked as A, B, C, D and E (fig. 1).

Results

The readings obtained are shown in table 1. The results are presented in Figure 2. It may be noted that there is a very definite upward trend in slow-neutron count rate with decreasing gap between the concrete foundation and the metal sheet, confirming our theoretical prediction that neutron backscatter gauge can be use for the detection of gap.

Conclusion

It is seen that the change in the count rate due to the change in distance between the plate and the concrete foundation is a measure of the gap. The neutron backscatter gauge is thus very well suited for the purpose and needs further study for the calibration of the gap distance with the count rate.

The measurements using neutron backscatter gauge not only gives information about the gaps but also indicates the presence of water/oil leakage below the tank floor due to the cracks.

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Figure 1 Experimental arrangement for gap detection studies.

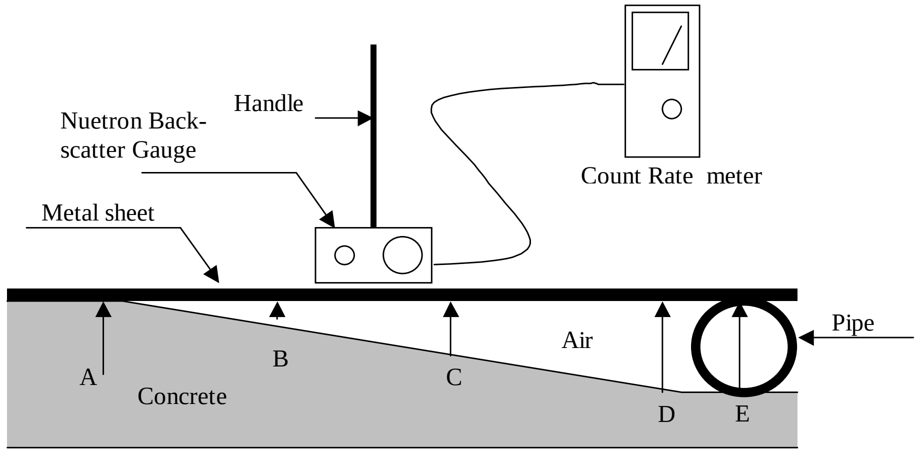

Figure 2. Slow-neutron count rate *v/s* distance between sheet and concrete

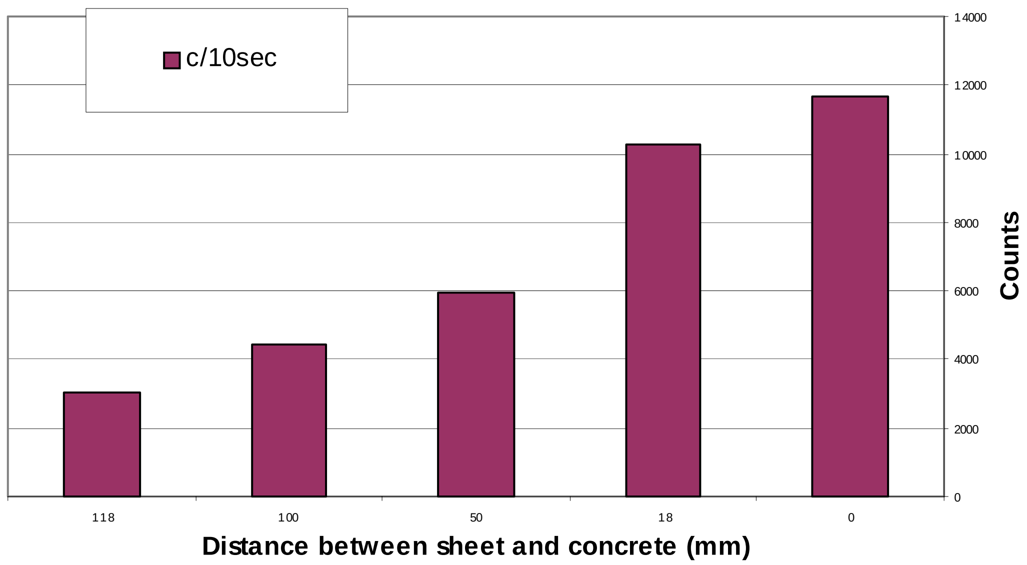

Table 1

Position	Distance/gap (mm)	Count rate C / 10 sec	Ratio
A	0	11642	1.00
B	18	10246	0.88
C	50	5958	0.51
D	100	4453	0.38
E	118	3017	0.26

Gaps in the foundation and bottom plate of storage tanks