Gauging

Detector Applications Information Note

Radiation detector assemblies (organic and inorganic scintillators detectors) are used in industrial and process control applications to determine physical parameters such as thickness and density. In addition, they can be used to verify package contents and parts presence or position. Applications fall into two broad categories: go/no-go and thickness measuring devices.

Gauges employ either transmission or backscatter techniques. (See Figures 1. and 2.) X-ray, gamma, or beta sources are used, depending upon the nature of the application. Beta gauges are appropriate for relatively low mass materials such as paper, plastic and films. These materials provide low attenuation to X-ray or gammas, which renders transmission devices unsuitable.

Backscatter gauges are used when only one side of the process has convenient access. Radiation from a source is also subject to backscatter from interaction with matter. For instance, beta particles can enter one surface of a material and be deflected back at a large angle after partial energy deposition.

The amount of backscatter is dependent upon atomic number and thickness. By positioning a detector at the same side as the source, a backscatter gauge can be configured to measure the thickness of material being processed.

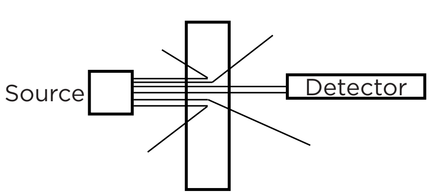

Figure 1.

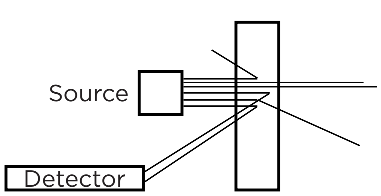

Figure 2.

Go/No-go Applications

A system which records the difference in signal between the presence and absence of intervening material finds go/no-go applications in parts presence systems, liquid level gauging and fill gauging.

Parts presence systems verify that a specific component is appropriately in-place. This technique is used when the component is located within packaging or walls which preclude the use of optical verification.

Liquid level gauging determines the height of a liquid in a closed container. This application can vary from relatively small containers, to water towers or refinery tanks.

Fill gauges are a specific application of level gauging. A source and detector are in fixed positions to determine the presence or absence of appropriate fill. For example, in a bottling plant, a fill gauge is positioned to verify fill in cans coming off the line. The detector records a nominal low signal when the liquid is in place between the detector and source.

When the liquid is below the nominal level, or missing, the normal attenuation does not occur. The detector records a high signal which typically would trigger a relay, diverting that container off-line.

Thickness/Density Applications

For thickness or density gauging, measurement precision is based on nuclear counting statistics. For continuous process measurements, this is a function of source strength, geometric efficiency, and sample movement speed.

Gamma and X-rays are attenuated by material positioned between their source and a detector. The attenuation is a function of the materials' density and thickness.

For a given material (such as aluminum or sheet steel), an appropriately-calibrated system measures the thickness of the material moving between the source and detector.

Gauging

Principles of Operation

Nuclear gauging relies on well-known principles. For example, a gamma ray backscatter gauge can be defined in terms of the Compton Effect. Compton scattering cross-sections and the correlation between the energy of the scattered gamma ray and the angle at which the gamma ray is scattered are well known.

Take the case of a ^{137}Cs source emitting gamma rays into a material of some density. The material scatters gamma rays in relation to the quantity of matter in the material. The Compton equation:

$$E_c = \frac{E_1}{1 + \frac{E_1}{mc^2}(1-\cos\phi)}$$

E_c = energy of the Compton scattered gamma ray

E_1 = energy of the ^{137}Cs gamma ray (0.662 MeV)

ϕ = the scattering angle

mc^2 = 0.511 MeV

gives the energy versus the angle of scatter. In Figure 3., the source and the detectors are collimated so that scattered gamma rays at a known angle (and therefore a known energy) are accepted. The collimators also define a range of depths within the material over which average density may be determined.

Two detectors are used to minimize errors caused by radiation scattering from construction materials between the source and material volume of interest.

The activity of the source used in these measurements is as high as 3 Curies. Each detector should record about 10,000 counts in the measurement interval to give a counting statistical reliability of 1% ($\sqrt{10{,}000}/10{,}000$). The more rapidly the gauge is moved, the greater the source activity required.

Detector Configurations

Scintillator/photomultiplier tube configurations can be designed for either pulse mode or current mode use, depending upon the details of the application. Inorganic scintillators such as NaI(Tl) or CsI(Na) are typically used for X-ray or gamma-gauging.

Plastic scintillators are used in level gauging applications involving large liquid reservoirs, such as tanks or towers. In these cases, large rods or bars provide more efficiency than gas-filled detectors and are more cost-effective than inorganic alternatives.

Plastic scintillator/photomultiplier tube configurations are used in beta backscatter devices.

Scintillator/photodiode configurations can be well suited for gauging applications. In current mode they can be used with no bias voltage. This provides a very compact, economical, rugged device with no high voltage requirement.

Gas-filled detectors are typically used at lower energies where they are most efficient.

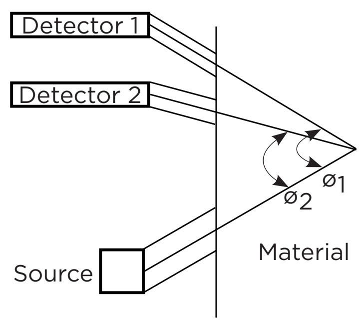

Figure 3.