Application Note

Neutron backscatter versus gamma transmission analysis for coke drum applications

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Key Words

- Control foam over
- Anti-foaming
- Drum utilization
- Delayed coker
- Nuclear gauges

Introduction

Hydrocarbon processing in today's petrochemical industry demands greater process control, as well as an increase in process efficiency and safety. Many operators of coke drums require a general overview of the height of materials and the rate of level as the process changes. Two technologies are usually applied to coke drums to determine their contents: neutron backscatter and gamma transmission. Neutron backscatter can detect vapors, foams, liquids and solids through any vessel thickness to provide rapid indication of process changes. Gamma transmission offers the ability to look at the height of foam, coke and water during the coking cycle, while providing vapor density compensation. When neutron backscatter and gamma transmission methods are used in conjunction, called "Hybrid Coking Level," they can offer superior insight into the process changes than if either method was used alone. The combination of the Thermo Scientific™ KRILPRO interface device and the Thermo Scientific™ LevelPRO nuclear gauge offers the best monitoring scheme for both exact control and an overview of what is happening in the delayed coking process.

Neutron Backscatter Measurement Principle

The process begins with fast neutrons being emitted by a source through the walls of the vessel (Figure 1). These neutrons collide with the nuclei of the process material. Due to these numerous collisions, some of these neutrons bounce back (are back-scattered) to the detector (Figure 2). The slow neutrons, those that have lost most of their energy during collisions, are detected by the detector. Since collisions with light atoms cause more energy loss than collisions with heavy atoms, the response of the gauge is more sensitive to the density of light atoms in the process.

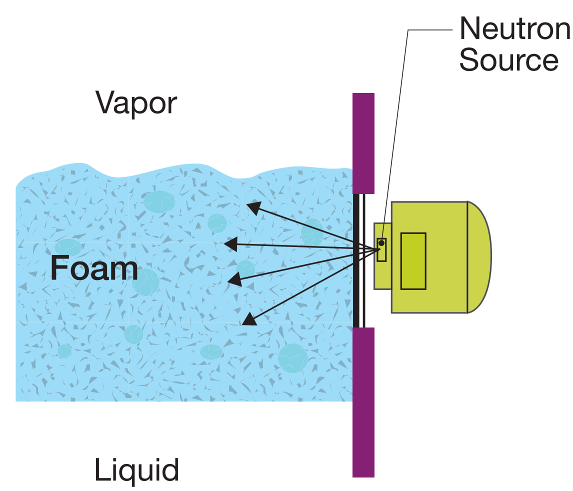

Figure 1. Fast neutrons are emitted to the foam sample non-intrusively from the neutron source, located outside of the vessel.

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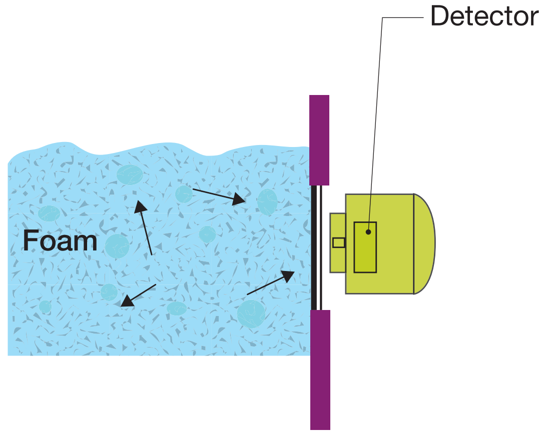

Figure 2. As a result of collisions, some neutrons bounce back to the detector.

Neutron Backscatter Applied to Coke Drums

The purpose of controlling the contents within a coke drum is to 1) maximize the outage (amount of hydrocarbons treated during each batch), 2) minimize the anti-foaming quantity to be used, and 3) avoid "foam over." The KRILPRO coke/foam interface device (Figure 3) meets these demands, offering both qualitative (level) and quantitative (% Hydrogen) controls, resulting from direct measurement. This is accomplished by reducing the source size by a factor of ten and the sensor stability and sensitivity offering a precision of ±0.0006% Hydrogen.

Figure 3: The Thermo Scientific KRILPRO interface device.

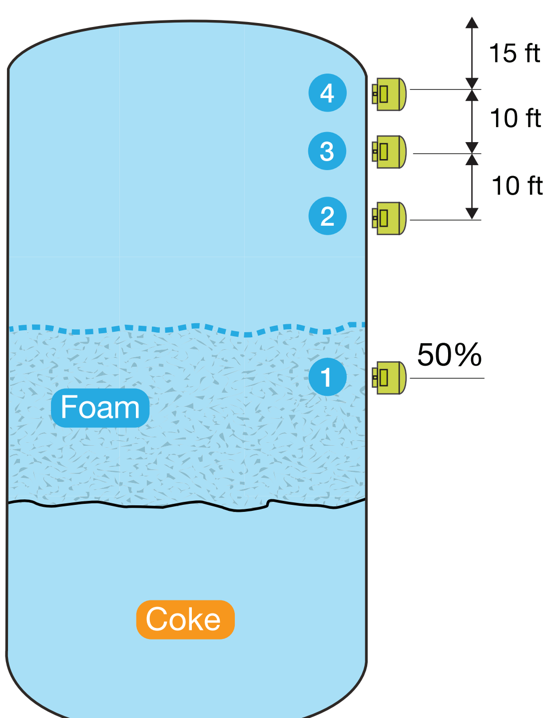

Figure 4. Typical mounting of detectors on a vessel for neutron backscatter.

Figure 4 shows a typical mounting scenario and the placement of the gauges on the outside of the vessel. The coker is loaded and the first (1) gauge monitors the material. It first detects the foam and then the wet coke. From the time difference, the volume of the foam can be calculated and the amount of anti foaming required can be determined. Most companies inject the anti foam when the foam reaches the second (2) gauge. The result of this action can be monitored by the second gauge, which should indicate 5% to 100% transition as the wet coke comes in. If not, correction can be taken. Gauge 3 will indicate to the plant to stop charging. Gauge 4 is used as safety indication to avoid "foam over" due to the sudden depressurization at switch time.

The signal coming from the detector is a current measured in pA (pico amps = 1.0×10^{-12} Amps). It depends on the wall thickness, the process material, and the distance of the detector from the process material. The calibration of the instrument is done taking two points: empty and full of water. The output (4-20 mA) is spanned as 0% to 100% output.

The calibration assigns the following values:

- Vessel empty: 5% = 4.8 mA
- Vessel full of water: 95% = 19.2 mA

With this setting, the following readings can be made:

- Light foam: 15% to 35%
- Heavy foam: 40% to 60%
- Coke saturated with water 85% to 90%
- Dry Coke: 70% to 85%

Gamma Transmission Measurement Principle

A gamma ray source, typically Cesiums-137 (Cs-137), is located on one side of the vessel and a gamma radiation detector is mounted on the other side (Figure 5). The gamma rays are attenuated by any material between the source and the detector (walls, foam, liquid). The signal from the detectors is proportional to the amount of radiation that reaches them.

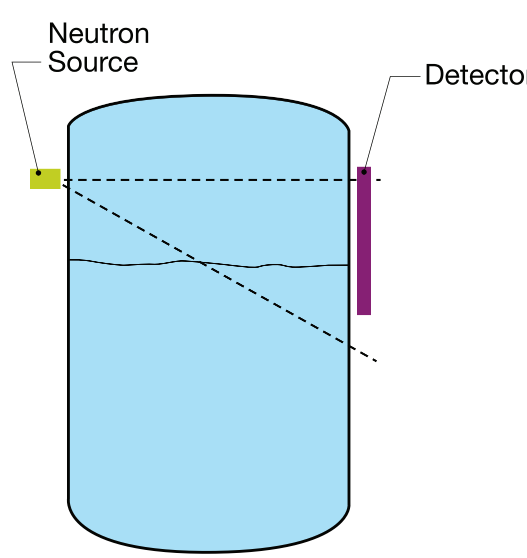

Figure 5. Typical mounting of detectors on a vessel for gamma transmission.

How Much Radiation Reaches the Detector?

The attenuation of gamma rays is proportional to the density of the material and the length of the path through that material. The formula is roughly att= exp(-0.0357 × density(lb/cft) × path length (ft)). If we have a coker with an internal diameter of 25 ft, we can calculate the attenuation for different materials:

- For **air** at 1 atm (density = 0.0813 lb/cft) we get att = exp(-0.0357 × 0.0813 × 25) = 0.93 This means that only 7% of the radiation would be absorbed by air and 93% of the emitted radiation would reach the detector.
- For **water** we get: att = 0.000,which means all radiation has been absorbed.
- For foam with a density of 6.25 lb/cft att = 0.004. This means that only 0.4% of the radiation reaches the detector which is equivalent to say that all the radiation has been attenuated by the foam.
- For the vapors (hydrocarbons), density will vary with the pressure. We will suppose a change from 0 lb/cft to 0.1 lb/cft. The corresponding attenuation is att = 1 to 0.914, i.e.: the vapor density change can affect the measurement by a maximum of 8.6%.

This calculation can be redone for different vessel sizes and with Cobalt 60 (Co-60) sources as well. The Co-60 sources are more energetic, therefore it has less attenuation than with Cs-137, but the half life for Co-60 is only 5.4 years versus 30 years for Cs-137. Tables 1 and 2 show the attenuation results for each source.

	ID Location	15 ft	20 ft	25 ft	30 ft
Coker with Cs-137 sources	Vapor at 0.1 #/cft	5.2%	6.9%	8.5%	10.2%
	Foam at 3.125#/cft	81.2%	89.3%	93.9%	96.5%
	Foam at 6.25 #/cft	96.5%	98.8%	99.6%	99.9%

Table 1. Attenuation results for coker with Cs-137 sources.

	ID Location	15 ft	20 ft	25 ft	30 ft
Coker with Co-60 sources	Vapor at 0.1 #/cft	3.9%	5.2%	6.4%	7.7%
	Foam at 3.125#/cft	71.2%	81.0%	87.5%	91.7%
	Foam at 6.25 #/cft	91.7%	96.4%	98.4%	99.3%

Table 2. Attenuation results for coker with Co-60 sources.

The results above show that the gamma transmission technique is affected by changes in vapor densities. It can affect the level measurement by 6.9% on a 20 ft diameter vessel using Cs-137. In addition, the attenuation of the radiation by the foam is very important; almost as much as for the liquid hydrocarbons or coke. This means that the level device will not be able to distinguish between the coke and the foam. It would also be impossible to determine if a change is due to a foam density change or a liquid/coke level change.

In summary, the gamma transmission continuous level technique will detect and indicate the edge of the foam level with an error associated to the density changes of the vapor of about 6.9% of span (sensitive length of the detector) per 0.1 lb/cft. The Thermo Scientific LevelPRO level gauge (Figure 6) is an ideal solution for detecting foam level, based off the gamma transmission technology.

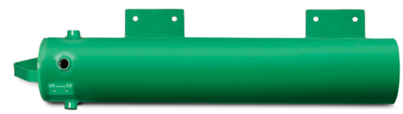

Figure 6. The Thermo Scientific™ LevelPRO level gauge.

Recommendations

A hybrid approach (Figure 7) will offer the customer the advantages of both systems. At the top of the span , an 8 ft or 10 ft continuous level gauge can track the foam/air interface to help the operators against foam over.

Redundancy at the top is highly recommended due to the cost associated with "foam over." That is, there should be a neutron backscatter devise and a gamma transmission continuous level device. The neutron gauge will identify what products are at that level and the transmission

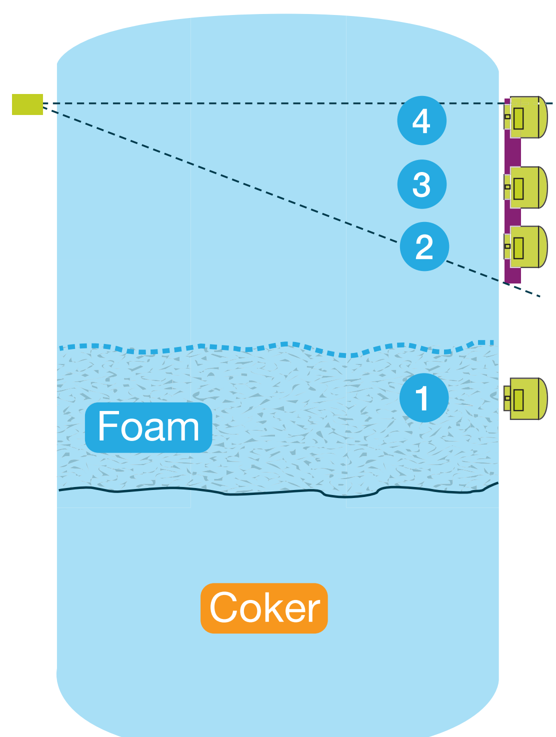

Figure 7. A hybrid mounting scenario with a neutron backscatter device and a gama level transmission device.

device will provide information on the progression of the front of material to the operators. Also, if one gauge fails, the operators are left with another measuring system to handle the coker.

In many cases, operators wish to track the rate of foam increase over a larger area up to 48 feet. Gamma transmission is used in conjunction with neutron backscatter for the larger area coverage. Multiple gamma detectors are cascaded to cover the increased level span along with three to four neutron backscatter units.

Conclusions

Using neutron backscatter in conjunction with gamma transmission (Hybrid Level) offers coke drum operators the most efficient and safe drum operations via:

- Monitoring rate of foam buildup
- Measuring density of foam for proper anti-foaming use age
- Ability to use higher levels of drum utilization (closer to chord line)
- Offer preventive monitoring controls for foam over protection

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