

# COMPLEX COKING CHALLENGES

**Logan Boatright, Neil Murch, and Bailey Stainsby, Tracerco**, discuss how solid-state neutron backscatter measurements can provide real-time insight into foam and coke levels in delayed coking operations, improving visibility and supporting safer, more efficient drum control.

Coke drums in delayed coking units are among the most difficult vessels in a refinery to monitor. They are typically up to 30 m tall and 10 m in dia., operating at around 500°C. In each 12 – 24 hr cycle, heavy residual oil is thermally cracked, producing lighter hydrocarbons that vaporise and leave the drum, while solid petroleum coke builds up on the walls.

At any given moment, the drum may contain vapour at the top, a frothy foaming oil phase, liquid oil, and accumulating coke solids – sometimes with water present during quench. The most critical interfaces to monitor are the rising foam and the growth of the coke bed. If operators lose visibility of these internal levels, foam can expand and ‘foam over’ into overhead lines, carrying coke-laden residual oil into downstream equipment. A single foam-over event can force an unplanned trip and a lengthy clean-up operation.

In short, a coke drum without accurate level and interface monitoring is an operational risk. It is difficult to run the unit close to optimum capacity and conditions without a clear view of what is happening inside.

## From gamma transmission to hydrogen-sensitive measurement

Because of the extreme temperature, pressure, and opaque internal environment, conventional level instruments, such as guided wave radar or ultrasonics, are generally impractical for coke drums. Many refineries therefore adopt nucleonic techniques early on, particularly gamma-based level measurement using sealed sources.

In a typical gamma transmission system, a source is mounted on one side of the drum and a detector on the opposite side. Radiation is attenuated by the process material, where the detector signal is inversely proportional to the change in process condition to provide overall level. While this approach is robust in harsh conditions, it has limitations in a delayed coking service:

- Foam discrimination is poor. Gamma attenuation mainly distinguishes dense liquid or solid material from lighter vapour. A froth or foam layer, while typically lower in hydrogen density than water, may appear similar to liquid due to the overall signal attenuation of large diameter vessels.
- High source activities are often required. Penetrating thick steel and large geometries of coking vessels generally demands relatively high activity sources to ensure enough signal change can be measured. This potentially increases radiation exclusion zones and administrative controls.

Overall, gamma systems tend to offer only a coarse indication of level, providing little insight into the intermediate foam phase that operators are most concerned about. This gap has led to increasing interest in more appropriate technologies, which can distinguish vapour, foam, liquid, and coke more effectively.

## Neutron backscatter in practice

Neutron backscatter technology utilises high energy neutrons that pass through the drum wall and interact with the material inside. When a fast neutron collides with a light nucleus,

especially hydrogen, it loses energy rapidly and is scattered back as a thermal (lower energy) neutron.

A thermal neutron detector mounted alongside the source, in the same external device, measures the returning neutron flux. The count rate correlates with the amount of hydrogen in front of the instrument:

- High counts indicate hydrogen-rich foam or liquid.
- Low counts correspond to vapour or empty headspace.
- Transitions in count rate mark the interfaces between vapour, foam, liquid, and the growing coke bed.

Because the source and detector are co-located, multiple neutron backscatter devices can be installed at different elevations on the drum. In one implementation, an array of up to four detectors is spaced vertically, providing several 'windows' into the vessel. Operators can then follow the upward progression of foam and the growth of the coke bed throughout the cycle, rather than relying on a single high-level trip.

Continuous, real-time measurements allow the control system to generate trends and alarms. As foam climbs towards a predefined elevation, operators can time anti-foam injections and adjust feed or steam conditions based on measured behaviour rather than expected patterns. If an upper sensor begins to register coke earlier than anticipated, it can indicate a change in coking rate or a need to review heater outlet temperature and drum switching strategy.

Because neutron backscatter is fully external and non-intrusive, it is largely unaffected by internal temperature and chemistry. The technique therefore provides a more detailed and repeatable view of the drum's internal state than a single-point gamma transmission measurement, turning what has historically been a 'black box' into a monitored process unit.

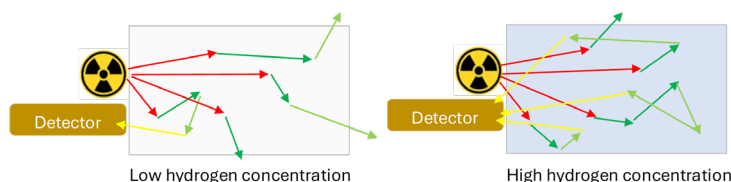


**Figure 1.** Visualisation of the neutron backscatter technique.

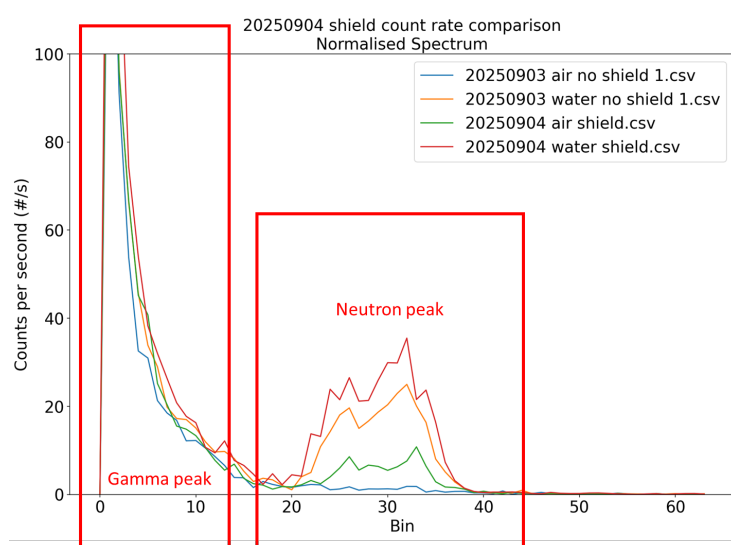


**Figure 2.** Effect of shielding on neutron peak.

## Solid-state detection and shielding design

Neutron backscatter itself is not new; legacy devices using similar measurement physics were deployed on delayed cokers for several decades. What has now changed is the development of more reliable solid state sensing technology.

Earlier instruments typically employed gas-filled proportional counters with Helium-3 or Boron-Trifluoride (BF<sub>3</sub>). While sensitive, these detectors introduced several practical issues noted by operators:

- Helium-3 is scarce and expensive.
- BF<sub>3</sub> is a toxic gas that requires careful handling and leak management.
- Gas tubes age over time, can lose their fill, and may require periodic re-gassing.
- Sensitivity to background gamma radiation can necessitate additional shielding.

In contrast, a modern neutron backscatter instrument, such as Tracerco's DrumVision™, uses a solid-state scintillation detector based on Lithium-6 (Li-6) doped glass. This creates light during interactions with thermal neutrons that can be detected by a photomultiplier tube and an electronic system.

In operating terms, this design has several practical benefits:

- Detectors retain stable performance over a wide operating temperature range, reducing the need for repeated temperature compensation.
- Scintillator materials are more readily available than Helium-3, improving long-term reliability.
- There is no pressurised detector gas to leak or replenish, so operators are not faced with scheduled re-gassing or unexpected detector ageing.
- Removing BF<sub>3</sub> eliminates a potential health hazard in the event of mechanical damage.
- One early trial highlighted another difference: an older gas-based unit on the same site required relatively frequent temperature compensation and attention to maintain data quality. By contrast, the solid-state system was factory-calibrated and did not require repeated adjustment during start-up and early operation, which reduced the amount of required coke drum maintenance.

The housing incorporates a layered neutron shielding system to significantly reduce operational exposure compared to legacy systems. Between the isotope and the external metal enclosure, boron-loaded high-density polyethylene (HDPE) slows down fast neutrons and captures a large fraction of the resulting thermal neutrons. Testing showed that this configuration requires a radiation-controlled area around the device at about 30 cm, keeping operator exposure within conservative site limits.

An intended benefit of this enhanced shielding design is a small, stable background of thermalised neutrons that scatter back into the detector even when the drum is empty. The instrument uses this background signal for automatic baseline calibration, avoiding the need for separate calibration sources or specific process conditions before meaningful data are available. The source itself is mounted within a mechanical system that allows it to be retracted into a shielded position when the device is disarmed or taken out of service.

## Integrating with existing assets

A practical consideration for many refiners is how easily new technology can be retrofitted to existing units. In the case of legacy neutron systems, a significant installed base of obsolete devices exists on coke drums worldwide. Many of these instruments are now unsupported, leaving operators with equipment that may be unreliable or difficult to maintain.

To address this, DrumVision has been designed to fit existing vessels where obsolete neutron backscatter devices exist. In Tracerco's trial installations, this has allowed the new unit to be installed as a drop-in replacement, without vessel modification or hot work. Electronics are housed in a rugged, explosion-proof enclosure suitable for hazardous areas, and can utilise existing site cable connections.

Once installed and commissioned, the instrument is intended to operate with minimal routine intervention. Typical design life is of the order of 30 years, ensuring maximisation of production uptime and minimisation of typical maintenance workload.

Coker cycle on the coker measured by the Tracerco DrumVision neutron backscatter device

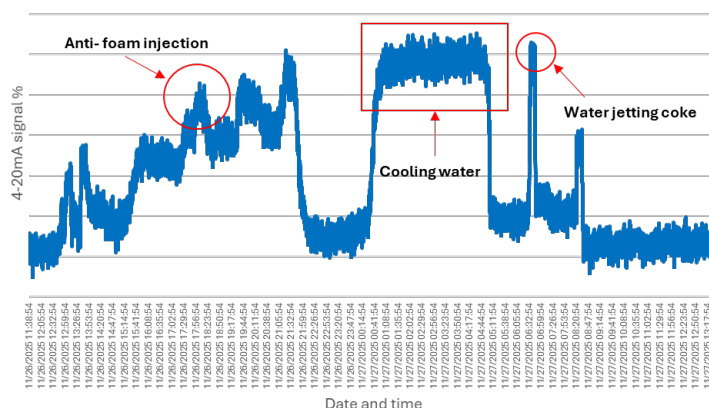


**Figure 3.** Graph showing full coker cycle using the neutron backscatter method.

## Field experience and operational impact

In one refinery trial on a delayed coking unit, the device was installed at one point on a vessel that had previously relied on a legacy system, a gamma-based high-level trip and conservative operating practices. Over multiple cycles, the system accurately tracked foam growth and coke bed position in real-time. Plotting this data against drum pressure, heater outlet temperature, and operating conditions allowed the client's process engineers to compare assumed drum behaviour with actual measured conditions.

The result of the trial led to several operational realisations:

- Anti-foam injection strategy was refined and improved, moving away from near-continuous dosing to more targeted injections based on actual and measured real-time foam growth data.
- Start-up and quench sequences were optimised using the measured interfaces, helping operators understand in real-time the nature of how the foam head responded to changes in steam and pressure.
- Post-trial, the customer had the confidence that they no longer had to rely on a single gamma switch which limited their production visibility to a single point in the process.

During the initial run, the operators and maintenance staff emphasised the enhanced stability through start-up and normal operation, in contrast to their experience with obsolete helium-filled detectors. Operators have highlighted several advantages compared with gamma-only approaches. For example, one customer noted that it now has full visibility in the column, rather than only the upper surface near a trip point, and the ability to position detectors to monitor specific interfaces of interest, such as the region between the coke bed and foam.

## Data-driven delayed coking

As refiners move towards greater levels of digitalisation, automation, and advanced process control, coking units remain a challenge. The batch nature of the process, the hostile environment inside the drum, and the lack of direct process interface measurement have historically led to refiners conservatively running production based on limited data and estimations. 