Moisture measurement with neutrons

Moisture measurement of raw materials, particularly for blast furnaces, is extremely important if good control over hot metal quality is to be obtained. Use of neutron exposure provides a rapid, continuous and non-invasive moisture measurement with an accuracy of ±0.2 to ±0.5% depending on the material to be measured.

AUTHOR: Matt Barlett
Berthold Technologies

Process control has integrated into every aspect of steelmaking, from the production of coke and iron to the analysis of pickling acid. The blast furnace in particular is an important process step, providing hot metal for subsequent steelmaking operations. There are many variables that must be controlled in order to economically produce consistent hot metal quality. Some of the most important of these are the moisture content of coke, sinter and iron ore.

One of the more successful and widely used methods for measuring raw material moisture is to expose the material to neutrons as it is rapid, repeatable, automatic and does not require samples to be taken from the raw material supply.

PRINCIPLES

This system consists primarily of a neutron source, shield, measurement detectors and an evaluation unit that is used to calculate the moisture content of the product.

The principle is based on the interaction of fast neutrons and hydrogen atoms. Fast neutrons are created using an americium/beryllium ($Am^{241}Be$) radionuclide where neutrons have a mass similar to that of the nucleus of a hydrogen atom – the mass of all other nuclei can be 10–200 times greater. When the fast neutron strikes a much greater mass than itself, it is deflected without a significant loss of energy. However, when it collides with a hydrogen nucleus it imparts approximately half of its energy to the hydrogen nucleus. After several of these collisions, the neutron is moderated to 'thermal energy' classification where E<1 eV. This causes a cloud of slow neutrons to form around the fast neutron source. The detection of these slow neutrons takes place with the use of helium-3 (He^3) proportional counter tubes. Thus the amount of slow, or thermal, neutrons present in the material is dependent on the hydrogen content per unit volume of material, and therefore on the moisture in volume%. Other sources of hydrogen are considered constant in the coke as the major measurable changes come from the moisture and not from chemically bonded hydrogen. The measurement volume needed to capture

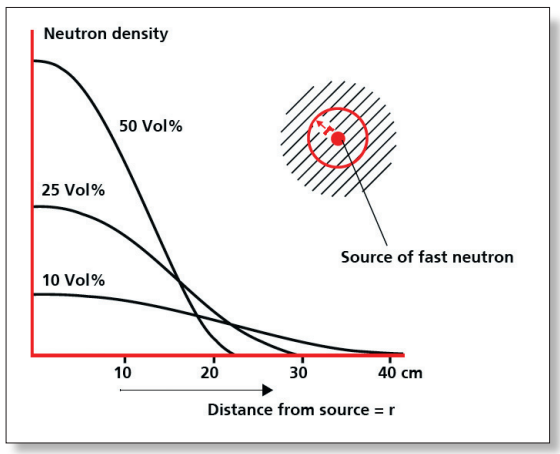

Fig.1 **Moisture measuring volume**

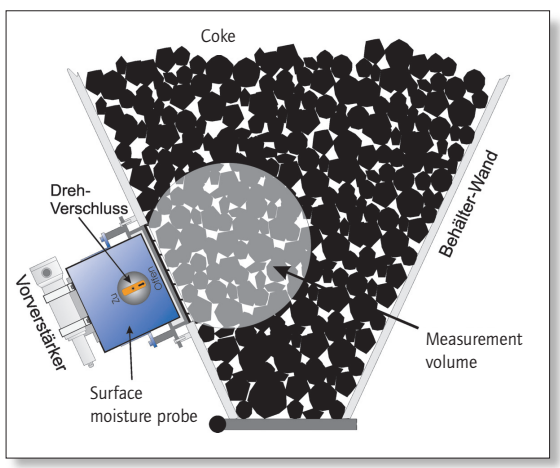

Fig.2 **Surface mount configuration**

95% of all slow neutrons can be expressed as follows:

$$D=30x3\sqrt{(100/Fv)}$$

where Fv is the moisture in volume% and D is the diameter of the measurement volume in cm. *Figure 1* shows the density of thermal neutrons at different volume moistures.

There are two common configurations where neutron measurement can be taken. The first is on the surface of the hopper. *Figure 2* shows the typical arrangement. Cutting a hole in the bin wall and removing the inner

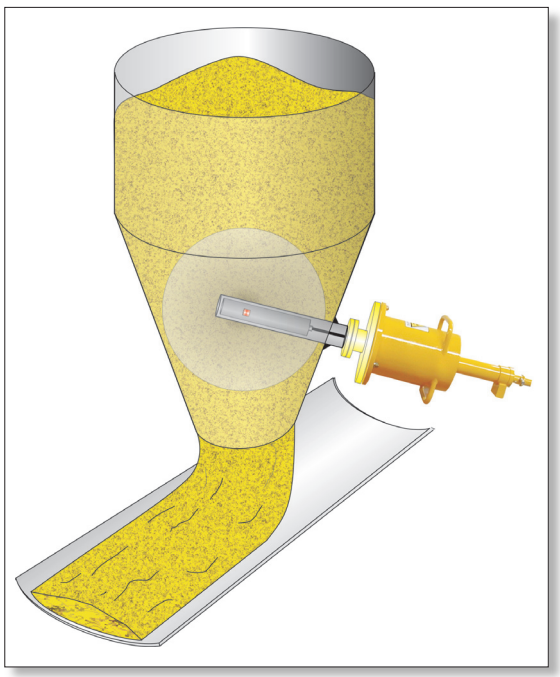

Fig.3 **Insertion configuration**

lining allows the user to insert a specially designed mounting frame that is coated with a very hard ceramic surface having a Mohs hardness rating of 9. (In comparison, the Mohs hardness rating of diamond is 10.) This protects the mounted unit from material abrasion. Beneath the ceramic liner, or wear plate, is a signal wire that will produce an open circuit if the ceramic wear plate is compromised by the material inside the hopper. This ensures the integrity of the stainless steel unit which houses the source and detectors. There is also a neoprene rubber gasket between the mounting frame and the ceramic wear plate to minimise possible shock to the counter tubes by sudden filling of the hopper. The surface unit produces a measuring sphere of approximately 60cm in diameter. The slow neutrons are captured by two He^3 counter tubes located near the fast neutron source.

The second arrangement is the bunker probe or insertion configuration as shown in *Figure 3*. With this method, a stainless steel dip pipe is inserted into the hopper. The neutron source and counters are positioned inside the dip pipe allowing for approximately 40% more measuring volume than the first method. The dip pipe is coated with the same ceramic material as used with the surface mounted configuration.

When the material being measured has the tendency to vary in bulk density, density compensation is required. Two methods are usually used. The first is the transmission method. A section of the hopper is chosen close to the moisture measurement where a secondary gamma radiation source can be attached and a scintillation counter is used opposite the source to read the gamma energy that is passed through the material.

The second method is the backscatter method. This uses a smaller gamma source attached to the hopper wall with a detector to measure the reflected gamma rays.

The system also comes equipped with a hold signal that allows for fast batch filling processes. The hold signal allows the evaluation unit to 'freeze' the signal when the hopper is empty for as long as it is empty in order to make sure the measurement does not need to build up from an empty hopper value. This signal can be taken from a limit switch at the hopper discharge or from a signal from the weighing system.

Calibration of the system is taken from empirical data supplied by the laboratory and, as is inherent in these cases, the system is only as accurate as the samples analysed from the laboratory. Neutron moisture measurement can, however, show inconsistencies in laboratory results with the same product samples due to the fact that when a good calibration is set, the neutron meter itself is often more accurate than the laboratory. Taking into account the statistical error found in laboratory results and slightly varying densities the measurement typically has an accuracy of ±0.5% for coke moisture, ±0.3% for iron ore and ±0.2% for sinter. These accuracies relate to material density and moisture level, for instance coke has a density of 0.5–0.8g/cm^3 whereas sinter is 1.8–2.5g/cm^3. Typical moisture levels are: coke: 0–20wt %, iron ore: 0–15wt % and sinter: 6–8wt %. Since the moisture % is always related to the weight or mass, the 20% moisture in the light coke is still less water than the 8% in the heavy sinter. But the total amount of water also determines the measuring effect (count rate) and thus the statistical accuracy.

After initial calibration the system requires very little maintenance and adjusting the calibration is not necessary. Quite often the gauge will run for years without service. A calibration check plate is offered as an option for some users to provide a baseline to check the initial calibration in the event that inaccuracies occur between the gauge and the laboratory results. The check plate, consisting of polyethylene doped with boron, is simply placed in front of the neutron source to attenuate the neutron field and provide a consistent and repeatable value.

The neutron moisture measurement system has been proven as a reliable and repeatable application worldwide to give accurate readings allowing blast furnace personnel to effectively cut costs and improve quality. MS

Matt Barlett is Steel Products Manager, Berthold Technologies, LLC, USA

CONTACT: matt.barlett@berthold.com