Bioenergy Insight

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Explosive potential

Landfill gas goes from hazard to green opportunity

Replacing an old king

Spotlight on torrefied biomass

Regional focus: bioenergy in Canada

The number one source of information internationally for biomass, biopower, bioheat, biopellets and biogas!

Bioenergy companies can minimise the risks of spontaneous heating and spontaneous combustion through effective temperature measurement

It's getting hot in here

Biomass is increasingly being used as a fuel for power generation because it is sustainable and has the potential to be carbon-neutral in the medium term. In some cases, biomass is co-fired with coal, but a number of electricity generating units have been converted to run on 100% biomass. Although they have many desirable characteristics, biomass fuels – such as wood chips and pellets – have a number of properties that make them difficult and potentially dangerous to store and transport.

The most serious of these is their susceptibility to spontaneous heating and to spontaneous combustion. Fortunately, a number of techniques are available, which can detect the early stages of spontaneous combustion, allowing the problem to be detected in time to take preventative action and avoid a potentially damaging and costly fire. The best technique depends on the measurement location and the most appropriate choice is the one that best balances the advantages and drawbacks of each technique.

Combustion is a very real risk in bioenergy plants

Fuel choice

Hog fuel (coarsely shredded wood waste) can be used for power generation, but it has a number of drawbacks. It has a high moisture content that increases transport costs and also reduces the amount of heat available to produce steam and hence generate electricity. This is because the moisture must be evaporated in the boiler and the latent heat of vaporisation is lost when the water vapour exits through the stack. Hog fuel also has variable size distribution, and often contains foreign material, such as soil, rocks, grit, and even metal. Because of this, it is best burned on a moving grate combustor rather than a pulverised fuel boiler.

Wood pellets are generally preferred for large-scale electricity generation. They have a low, predictable moisture content and a high energy density, which reduces transport costs. They are generally free of contaminants and have predictable mechanical properties, so they can be ground in a pulveriser, which allows co-firing with coal or even direct substitution for coal. In most ways, they are easier to handle than hog fuel, though they do tend to disintegrate if they receive rough handling.

Torrefied wood pellets are made from wood chips that have been roasted at a temperature of around 300°C in an oxygen-deficient atmosphere. This process removes moisture and volatile organic compounds and allows the production of pellets with low moisture content and an energy density close to that of coal. The torrefaction process loses around 15% of the heat content of the raw wood, but it produces a material that is sometimes referred to as "biocoal". It is less expensive to transport than either hog fuel or conventional pellets, and it requires fewer modifications to a coal-burning plant's fuel handling system.

Heating mechanisms

There are two principal mechanisms that lead to spontaneous heating in woody biomass – oxidation and biological action. Biological agents include both bacteria and fungi and their actions are generally the first stage in spontaneous heating

Aside from the hazards associated with spontaneous combustion, spontaneous heating consumes the fuel and reduces the amount available for use in the boiler. Some reports indicate that as much as 1% of the fuel in an open storage pile can be consumed every month through bacterial action alone.

A number of factors determine the rate of heating. High moisture content encourages both fungal and bacterial activity. Bark and leaves provide nutrients for fungi and bacteria. Solar heating at the surface of a storage pile can encourage bacterial action. All of these factors are more likely to be present in hog fuel stored in the open than in pellets stored in an enclosed silo.

Bacterial and fungal action give rise to carbon dioxide (CO_2) and methane (CH_4). The amount of gas produced is an indication of the extent of the spontaneous heating. The early stages of combustion produce a large amount of carbon monoxide (CO), so the presence of this gas is an indication that spontaneous combustion is taking place.

Once the temperature is high enough, oxidation becomes the principal heating mechanism. Poor air circulation in the middle of the pile allows heat to build up, which can lead to a runaway effect as the higher temperature increases the rate of oxidation. A fire can begin to smoulder slowly in the middle of the pile, gradually working its way to the surface, where it will burst into flames when exposed to a plentiful supply of oxygen from the air.

Spontaneous heating and spontaneous combustion have tell-tale signs. The most obvious of these is an increase in temperature. It may take a long time for a temperature increase to become apparent if the reaction is taking place deep inside a storage pile, but elevated temperatures are much more apparent when the material is loaded onto a conveyor.

Detection options

The most effective method for detecting the presence of spontaneous heating or spontaneous combustion depends on the location.

Gas detection: CO

Carbon monoxide (CO) detection gives a fast and unambiguous indication that spontaneous combustion is taking place. The concentration of CO in ambient air is very low, and a lot of this gas is produced as spontaneous combustion begins, so a rapid increase in CO concentration is a sure sign that action is needed.

Most CO monitors used in biomass applications use electrochemical sensors. These are compact, specific, and very sensitive, with typical detection limits in the region of 2 parts per million. These sensors do have drawbacks, however. The most serious is that they give zero output when they fail, so a faulty sensor is indistinguishable from a safe condition. It is important with a CO monitoring system to perform regular calibration verification to ensure that the sensor is functioning correctly. A weekly verification is generally adequate.

Although this can be done manually, an automatic check ensures that the check is done consistently, and it removes the possibility that it can be neglected because plant personnel have other priorities. Continuous exposure to the target gas leads to a reduction in the sensor response, so some systems use a pair of sensors that are alternately exposed to the sample and to ambient air, allowing continuous measurement without degradation of accuracy.

Because it measures the gas concentration, CO monitoring is only effective in enclosed spaces, such as silos and pulverisers. It cannot be used in open storage areas because wind and other air movements will disperse the gas before the concentration becomes high enough to measure.

Both in situ and extractive systems are available. Although in situ systems are the simplest and least expensive, calibration verification is more difficult than for an extractive system, which allows calibration gas to be injected at the sample probe. The high concentration of dust in the headspace of a silo or in a pulveriser, especially, means that plugging of the sample port can cause problems. Regular inspection and cleaning of in situ probes is essential. For extractive systems, a blowback system employing compressed air can be employed to clean the sample probe automatically, and a flow sensor in the analyser can provide an indication that manual cleaning may be needed.

Measurement of CO in pulverisers is especially important. Along with the risk that burning material could be introduced, the mill performs a great deal of mechanical work in crushing the fuel that, in itself, can lead to a fire or explosion. The explosion risk is small when the mill is in operation because the particle concentration is above the upper explosive limit, but

Hog fuel can be used for power generation, but it has many drawbacks, Ametex says whenever the mill is started or stopped the concentration inevitably passes through the explosive range and, if burning material is present in the mill at this stage, an explosion is extremely likely.

Gas detection: CO_2 or CH_4

The presence of carbon dioxide and methane is an indication that biological action is taking place, and the concentration of these gases can be used to indicate the extent of such heating. As with CO measurements, these gases can only be measured effectively in enclosed spaces.

Most sensors commonly use infrared absorption to detect CO_2 and CH_4. Compact IR sensors are less sensitive than electrochemical cells, but detection limits of a few hundred parts per million are adequate to show whether spontaneous heating is taking place. These measurements are most effective when combined with a CO sensor, since they can be used to show when spontaneous heating becomes spontaneous combustion. An extractive analyser measuring CO, CO_2 and CH_4 allows a common sample system and control electronics to be used for all three gas sensors.

Temperature measurement

The actions of bacteria and fungi cause an increase in the temperature of a storage pile, whether open or enclosed. It is generally impractical to detect this temperature rise by direct measurements with thermometers or thermocouples because the material is regularly moved to the combustor and because of the size of the piles. Although these instruments only look at the surface of the stored material, the measurement of the infrared radiation emitted by the pile does provide an indication of its temperature and, therefore, of the heat being generated inside the storage pile.

The simplest method for scanning a storage pile is by using a hand-held thermal imager. Such devices are relatively inexpensive, but the intermittent measurement means that spontaneous heating can go undetected.

A fixed imaging system is preferable, since this allows images to be stored and compared over time. Image processing software further allows the temperature to be measured over different zones of the storage pile, and it also can exclude short-term fluctuations, such as a vehicle passing through the field of view.

	Thermal imaging	IR line scanning	Gas measurement
Outdoor storage	****	*	*
Indoor storage	****	*	**
Conveyor	**	****	**
Silo	***	*	****
Pulveriser	*	*	****

Table 1: Selection choices for detection of spontaneous heating and spontaneous combustion

> Spontaneous heating and spontaneous combustion pose risks at all sites that handle and process woody biomass

A highly effective temperature measurement can be made on a conveyor using a line-scanning infrared pyrometer that uses a single detector with a high-speed scanning mirror to make up to 1,000 discrete temperature measurements across the width of the conveyor. The movement of the conveyor allows the scanner software to build up a two-dimensional image of the material on the belt and show any hot spots associated with burning material.

Thermal imaging can also be used inside a silo to measure the surface temperature of the stored biomass. Although this method cannot measure the temperature of hot material deep within the silo, the hot gases produced by spontaneous heating carry heat to the top of the pile, and so a thermal imager can detect an abnormal temperature profile.

Once spontaneous heating or spontaneous combustion has been detected, appropriate remedial action must be taken. The best course of action depends on the location and severity of the problem. For example, a storage vessel can be inerted with nitrogen or steam.

Burning material can be diverted from a conveyor so that it does no more harm. In some cases, the best action can be to burn the fuel in the boiler in order to empty a storage vessel.

Practical experience

Ametek Land has used a variety of measurement methods to detect spontaneous heating and spontaneous combustion in fuel handling and storage systems used for woody biomass, as well as for traditional fuels such as coal. Silowatch extractive CO monitors were installed in pellet silos at one of the largest biomass electricity generating facilities in the UK.

ARC thermal imagers have been used inside storage domes and silos in the UK and in the Middle East. The Land HotSpotIR line scanning pyrometers have become the industry standard on a variety of conveyors from wood pellets to pet coke. In all cases, the analysers which all have variants approved for use in hazardous area locations have provided valuable information to the plant operator and have assisted in maintaining high levels of reliability and safety at the site, allowing the plants to provide evidence of automated detection systems that have aided conversations regarding insurance risk on the plants.

Spontaneous heating and spontaneous combustion pose risks at all sites that handle and process woody biomass. An appropriate choice of detection methods can significantly improve site safety. Gas measurements are most effective in enclosed spaces, while temperature measurements are the best choice for outdoor locations. ●

For more information:
This article was written by Derek Stuart and Richard Gagg, global product managers at Ametek Land. Visit: www.landinst.com