Detecting Spontaneous Heating in Biomass Pellets

By Derek Stuart, Global Product Manager, AMETEK Land, Dronfield, United Kingdom

Wood pellets have many desirable properties when used as fuel: they are sustainable, energy-dense, have low moisture content and are easy to transport. They can be burned in place of coal with relatively straightforward modifications to the fuel-handling system. However, they do oxidize easily, and this means they are susceptible to spontaneous heating which, left unchecked, can lead to spontaneous combustion. Fortunately, techniques are available which allow oxidation to be detected at an early stage so that preventative measures can be taken long before a damaging fire breaks out.

Risks of unwanted combustion – potentially causing injury, damage and/or downtime – occur everywhere pellets are handled, processed or stored. Safe handling practices are designed to ensure that the fuel remains intact throughout its journey from the mill until the point at which it is ignited in the boiler. This article examines equipment selection and operating criteria for reducing risk in storage areas, transfer points and in mills that pulverize the fuel before burned.

Oxidation is a critically important problem. When woody biomass is exposed to the air, the volatile components combine with oxygen in an exothermic reaction, leading to spontaneous heating. If there is adequate ventilation, this heat can disperse naturally and any increase in temperature does not cause a problem. If the heat cannot disperse, the pellets begin to warm up and a problem can develop. The Arrhenius equation tells us that the rate of oxidation approximately doubles with every 10 °C increase in temperature, so a runaway condition can occur in which the fuel eventually self-ignites in a process of spontaneous combustion.

There are several techniques which can give an early warning that a dangerous condition may occur. Those techniques work by detecting one of the tell-tale signs of oxidation – either heat build-up or the emission of carbon monoxide (CO) gas.

Choosing the most-appropriate monitoring technique depends on both the measurement location and the degree of risk. More sophisticated, and therefore more expensive, monitors are appropriate where large volumes of pellets are being handled and the consequences of spontaneous combustion are more serious.

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) gas detection offers a fast, sensitive means to detect the presence of oxidising fuel, as the oxidation process inevitably produces large amounts of CO and is a precursor to an actual fire. Large amounts of CO are produced by
the inefficient oxidation associated with spontaneous combustion. Ambient air contains a very low concentration of this gas – usually well below 10 parts per million (ppm) by volume - so a significantly higher concentration provides a fast and highly accurate early indication that unwanted oxidation is occurring. CO measurement has the advantages that very sensitive CO sensors are available with detection limits of 2 ppm or less. CO monitoring is fast, specific and sensitive, and can be calibrated to determine alarm levels that reliably identify a hazardous condition, while minimising the occurrence of false alarms.

Most CO monitors for biomass applications use electrochemical sensors. These are compact, specific and very sensitive, with typical detection limits in the region of 1 to 2 ppm. They 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 where no CO is present. 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 it is done consistently, and 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 pulverizers. 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 insitu and extractive systems are available. Although insitu systems are the simplest and least expensive, calibration verification is more difficult than for an extractive system, which allows a certified gas mixture gas to be injected at the sample probe. The high concentration of dust in the headspace of a silo or in a pulverizer means that plugging of the sample probe can easily occur,

**Figure 2.** AMETEK Land Millwatch CO monitors monitor CO levels in adjacent pulverizers.
and once the probe is blocked it can no longer sense the presence of CO in the atmosphere. A well-designed analyzer can detect a blocked sample probe by sensing a reduction in sample flow.

Regular inspection and cleaning of in situ probes are essential. For extractive systems, a blowback system employing compressed air can be used to clean the sample probe automatically, and a flow sensor in the analyzer can provide an indication that manual cleaning may be needed.

Measurement of CO in pulverizing mills 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 can, in itself, 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 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.

The sample probe for a CO measurement system, such as Millwatch, should be installed at the mill outlet so it receives a sample of well-mixed gases. AMETEK Land has developed an innovative sample system which does not penetrate into the gas flow. It comprises a large-area filter mounted in a side-arm outside the main pulverized fuel pipe. This has several advantages over older designs. The sampler is not directly exposed to the flow of pulverized fuel, so there is little abrasion and the lifetime of the sampler is increased. A blowback system uses compressed air to clean the filter periodically, increasing the time between manual cleaning operations. The sampler can be isolated from the fuel flow, allowing the filter to be cleaned or replaced while the mill is on-line.

Consideration must also be given to the gas path between the mill and the analyzer. For indoor locations, a simple stainless steel or Teflon tube can be used. For outdoor runs in cool climates, a heat-traced sample line is usually needed to prevent moisture in the sample from freezing and causing a blockage.

**Alarm**

One of the biggest challenges in configuring a CO measurement system is the determination of suitable alarm levels. A low alarm threshold gives the earliest warning of a problem, but it can result in an excessive number of nuisance alarms resulting from an unusual condition that is not causing any problems. An excessively high threshold can allow spontaneous heating to progress to the point of being hazardous. The exact value is specific to the fuel type and the storage location. For example, a CO concentration greater than 250 ppm can be seen during mill start-up, but in normal operation the CO concentration is in the region of 10 ppm. Millwatch analysers offer two independent alarm points, so an alarm level can be set at 300 ppm during start-up, and at 50 ppm for normal operation. Each plant’s operating parameters will eventually determine the proper levels of the dual alarms to provide the proper notifications while minimising nuisance alarms. This is achieved with a simple change of alarm levels on the Millwatch system.

An alternative to a level alarm is a rate-of-change alarm. This type alarm ignores the background level of CO but instead responds to the rapid increase that is associated with the early stage of spontaneous combustion.

**Temperature measurement**

Temperature measurements give a direct indication that spontaneous heating is taking place. Because of the time taken for heat to build up, a temperature sensor gives a slower indication of a problem than a CO monitor, but it can be used in an open area such as a conveyor where ambient air movements will disperse the carbon monoxide before a measurable concentration can accumulate.

Direct temperature measurements can be made using a thermocouple inserted into the material, for example within a storage dome.
Thermocouples have the advantage that they can measure deep within the stored material. This can be valuable because wood is a good insulator and buried hotspots are not always evident at the surface. However, there are several significant drawbacks to thermocouple measurements. They measure temperature at a single point, so a large array is needed if good coverage is a requirement. They also tend to break as the pellets are added to or removed from the pile.

An inexpensive portable thermal imager can be used to survey the surface of the pellets and give an instantaneous map of the temperature. This is an effective technique but it relies on the skill of the observer, and frequent measurements are expensive because of the time taken. A permanently-mounted thermal imager gives 24/7 coverage. Sophisticated image-processing software can detect elevated temperatures and provide an alarm if a threshold is exceeded. Improved spatial resolution can be achieved by using a thermal imager with a narrow field of view, mounted on a pan-and-tilt head. This allows the imager to repeatedly “patrol” the storage pile and detect any hot spots. Depending on the shape and size of the pile, multiple imagers may be needed to give adequate coverage. In most cases, the outputs from all the imagers can be combined in a single image processor which displays, the results, generates alarms and archives the data for future reference.

It is important to note that infrared temperature measurements can only determine the surface temperature so they may miss a buried hot spot. However, the heat generated by the oxidation will eventually warm the surrounding material, and the hot CO given off can transfer heat to the surface through convection. In a related application, Fierro et al. noted that “infrared thermography has been shown to be very efficient in hot spots detection in coal piles” and that losses calculated using the technique correlate well with those measured using thermocouple probes.

A variation on thermal imaging can be used to detect hot spots on moving objects such as conveyor belts. Line-scanning uses a single infrared detector and a rotating mirror which repeatedly scans across the moving object, perpendicular to its direction of travel. The combination of the scanning mirror and the linear movement of the conveyor allows the signal processor to build up a two-dimensional map of its temperature. A typical instrument can resolve 1000 points in each scan, with as many as 100 scans per second, giving very high spatial and temporal resolution. For hot-spot detection, the large amount of data produced can be simplified to provide a single value – the maximum temperature within the field of view.

A permanently-mounted thermal imager gives 24/7 coverage. Sophisticated image-processing software can detect elevated temperatures and provide an alarm if a threshold is exceeded.
**Figure 5.** Linescanning generates a two-dimensional thermal map of material on a moving conveyor.

<table>
<thead>
<tr>
<th></th>
<th>Thermal Imaging</th>
<th>IR Line Scanning</th>
<th>Gas Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dome</td>
<td>****</td>
<td>*</td>
<td>**</td>
</tr>
<tr>
<td>Conveyor</td>
<td>**</td>
<td>****</td>
<td>**</td>
</tr>
<tr>
<td>Silo</td>
<td>***</td>
<td>*</td>
<td>****</td>
</tr>
<tr>
<td>Pulverizer</td>
<td>*</td>
<td>*</td>
<td>****</td>
</tr>
</tbody>
</table>

**Table 1.** Selection choices for detection of Spontaneous Heating and Spontaneous Combustion.

Line-scanners can also be used to detect hot spots in rail cars, by measuring the temperature of the car itself, or in the stream of pellets as they are being unloaded from the bottom of the car.

**Remedial Actions**

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
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.

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 and petcoke. Silowatch extractive CO monitors were installed in pellet silos at a large biomass facility in the United Kingdom. ARC thermal imagers have been used inside storage domes and silos in the US and in the Middle East. HotSpotIR line scanning pyrometers have been installed successfully on a variety of conveyors. In all cases, the analyzers have provided valuable information to the plant operator and have assisted in maintaining high levels of reliability and safety at the site.

Conclusions
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; temperature measurements are the best choice for outdoor locations.

About AMETEK Land
AMETEK Land is the world’s leading manufacturer of monitors and analysers for industrial infrared non-contact temperature measurement, combustion efficiency and environmental pollutant emissions.

Founded in the UK in 1947, Land Instruments International Limited developed a reputation for producing innovative, resilient measurement technologies designed to operate in the most challenging conditions. Acquired by the Process & Analytical Instruments Division of AMETEK, Inc in 2006, today AMETEK Land is the premium supplier of product application solutions to world industries including biomass processing, steelmaking, glass making, minerals processing, hydrocarbon processing and thermal power generation.

Our success rests on award-winning technologies that push the limits demanded by the ever-increasing technical demands of global industry. Aligned with our expert knowledge, we meet the challenges of a wide range of applications, delivering process safety, process control and product quality our customers depend on.