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Dryer surface temperature measurement

Scope

Dryer section performance has a major effect on paper machine productivity and sheet quality. Production rates are frequently limited by drying capacity, which in turn is dependent on heat transfer from the steam in the dryers to the paper. To produce high rates of heat transfer to the sheet, high dryer surface temperatures are necessary. In order to achieve high quality, a uniform temperature is needed across the width of the dryers. Dryer surface temperature and temperature uniformity are therefore critical parameters in evaluating dryer section performance. The information that follows summarizes techniques and procedures that are available for measuring dryer surface temperatures. Suggestions for interpreting data are also included

Introduction

Surface temperature of a dryer is a good indicator of dryer performance. Difference between the temperature of the surface and the saturation temperature of supply steam is an indication of heat transfer efficiency from steam through resistances such as condensate in the dryer, the cast iron dryer shell, contamination on the inside and outside of the dryer, and air layers between the sheet and dryer.

A survey of dryer surface temperatures can reveal operating problems such as condensate buildup in dryers, incorrect syphon clearances, poor heat transfer due to variations in fabric and sheet tensions, and roll alignment problems. Such surveys provide valuable information for planning shutdowns to maintain dryers at peak performance.

Safety precautions

Follow normal safety precautions when working around paper machinery. Do not allow loose clothing or equipment to contact rotating machinery or ropes. Take special care when utilizing contact pyrometers to measure dryer surface temperatures. Beware of thermal and slip hazards around the dryer section.

Analysis of dryer performance

Temperature difference between steam and the dryer surface is the driving force for heat transfer from the steam, through the condensate layer inside the dryer and through the dryer shell to the surface. Similarly, temperature difference between the dryer surface and the wet paper is the driving force for heat transfer from the dryer into the sheet.

The equations that describe this heat transfer are:

$$q_1 = U_1 \times A_1 \times (T_s - T_d)$$

$$q_2 = U_2 \times A_2 \times (T_d - T_p)$$

where:

q_1 = Overall heat transfer rate from the steam to the dryer surface, kJ/hr (BTU/hr)

q_2 = Heat transfer rate from the dryer to the paper, kJ/hr (BTU/hr)

U_1 = Overall heat transfer coefficient from the steam to the dryer surface, kJ/m²-°C-hr (BTU/hr-ft²-°F)

U_2 = Heat transfer coefficient between the dryer surface and the paper, kJ/m²-°C-hr (BTU/hr-ft²-°F)

A_1 = Area of the dryer surface, m² (ft²)

A_2 = Area of paper contacting the dryer, m² (ft²)

T_s = Saturation temperature of steam, °C (°F)

T_d = Dryer surface temperature, °C (°F)

T_p = Paper temperature, °C (°F)

If one neglects the small heat loss to the environment from dryer surfaces exposed to air, then $q_1 = q_2$. As can be seen from these equations, dryer surface temperature does not, by itself, determine the heat transfer rate (or the drying rate). Low dryer surface temperature can be produced by either high heat transfer rates (typically good for drying) or high resistance to heat transfer (typically inhibiting drying). High resistance to heat transfer can result from a thick condensate layer (low U_1), or poor felting (low U_2). Small area of paper contact (A_2), such as in a lead dryer of a section with low paper and fabric wrap, will also result in higher than normal dryer surface temperatures.

Difference in temperature between the dryer surface and saturation temperature of steam is not sufficient by itself to determine if dryers are performing efficiently. To thoroughly evaluate the performance of a dryer section, condensing rate in the dryers must be known. This is discussed in TAPPI TIP 0404-33 "Dryer Section Performance Monitoring."

However, on the majority of paper machines, fabric and sheet tensions are fixed. Correspondingly, surface temperature is a good indication of drying performance. Comments noted in the section on interpreting data should be considered for evaluation of other cases.

Dryer temperature surveys

Reasons for conducting a dryer temperature survey dictate measurement techniques and the extent of data gathering. Measurements may be either part of a routine monitoring program or part of an extensive dryer section survey.

A. Routine monitoring. Routine monitoring is generally conducted for maintenance planning purposes and usually requires temperature data at only one cross-machine direction (CD) position on the dryer surface. This measurement is usually made from the tending side of the machine at a location approximately 0.5 to 1.0 m in from the edge of the sheet, to avoid edge effects. Dryer surface temperatures are compared to other dryers and to baseline data from previous surveys on the same grade and machine speed.

Operational data that should be recorded when temperatures are measured include furnish, machine speed, sheet weight, sheet width, production rate, and steam pressure and differential steam pressure in each dryer section.

Comparison of dryer surface temperatures is usually made using a graphical plot of temperatures, as shown in Figure 1. Suggestions for interpreting the data are given at the end of this technical information paper.

B. Detailed performance surveys. Detailed performance surveys are generally conducted when dryer sections are suspected of causing sheet moisture profile non-uniformities, or the dryer section is being considered for a major rebuild. These detailed surveys often include measurements of complete cross-machine direction temperature profiles of several dryer cylinders.

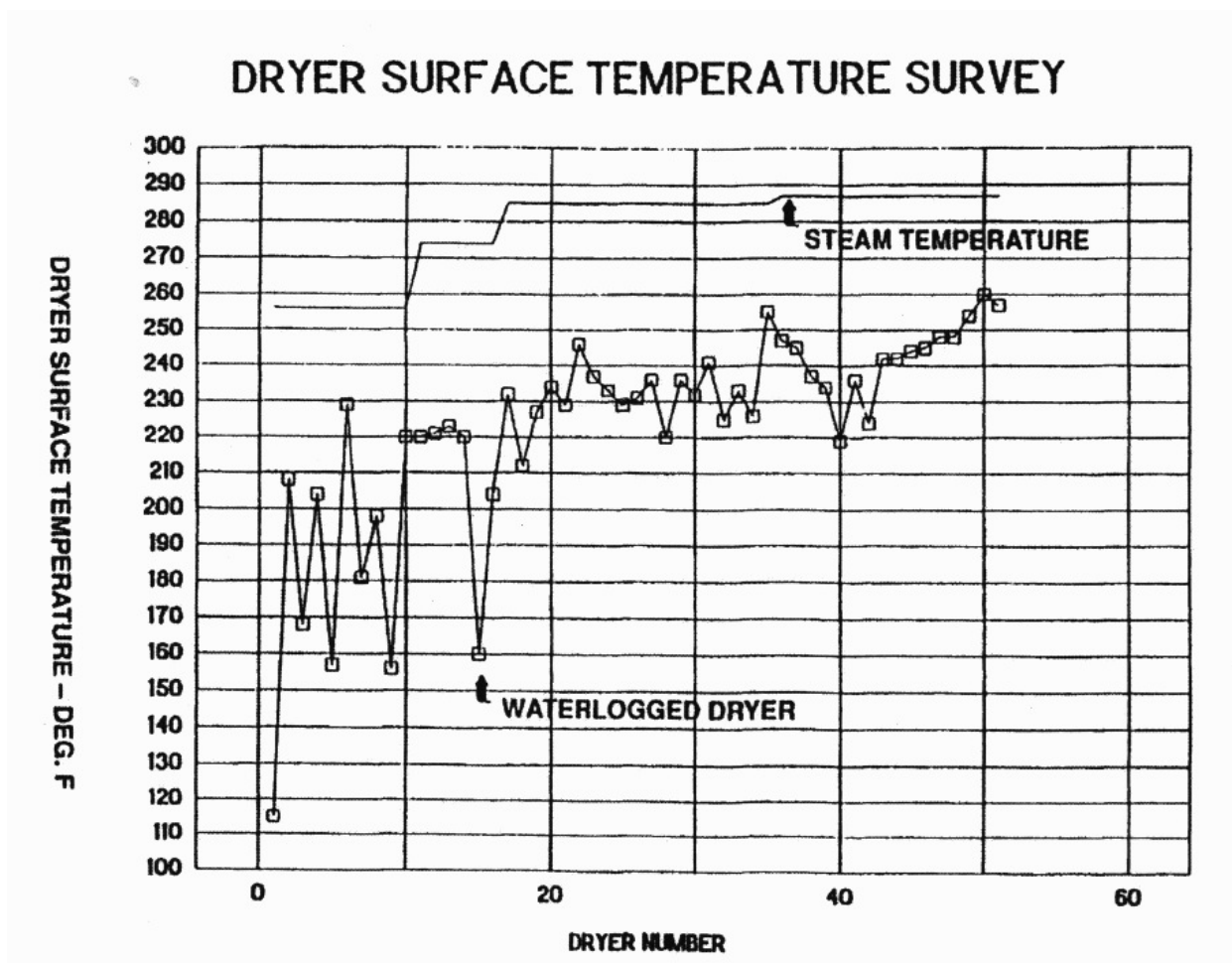


Fig. 1. Graphical display of dryer temperature survey results

Cross-direction temperature profile of the dryers has a major influence on sheet moisture profile. Investigation of causes of an uneven moisture profile requires measurement of dryer temperatures at several locations across the width of the dryers to determine if the dryers are responsible. Continuous cross-direction temperature profiles may be required to identify potential causes of moisture streaks. Examples of causes of moisture streaks include grooves in dryer shells, incorrect syphon clearances, and inadequate differential pressures.

Non-uniformity in dryer surface temperatures can also be the result of poor sheet moisture profile entering the dryer section. Although most detailed dryer temperature surveys use contact pyrometer instruments, infrared thermographic surveys have proven to be beneficial in evaluating CD temperature and moisture uniformity by monitoring paper, fabric, and dryer surface temperature. Such survey information can help to identify non-uniformities in entering moisture profiles.

Selection of instrumentation

Instrumentation used for dryer temperature surveys should provide repeatable and accurate temperature data. There are basically two types of instruments for measuring dryer surface temperatures: contacting devices and infrared instruments.

- A. **Contact pyrometers.** Contact instruments are placed directly on the surface of a dryer to measure its temperature. The measurement is made at least 0.5 m in from the edge of the sheet to avoid edge effects.

The sensor is generally mounted on the end of a long pole (frequently fiberglass or aluminum) that can be safely handled by the technician making the measurements.

Contact sensors must be compact to allow the technician to reach dryers through machine frame openings, and lightweight to allow the technician to position the sensor on the dryer and to cause minimal damage if accidentally caught between the sheet and the dryer. Frictional effects can be a problem with contact pyrometers. Friction heating increases with surface roughness, surface speed, and contact pressure.

A variety of instruments fall under the category of contact pyrometers. Some have sensor elements that contact the dryer surface directly; others have sensors that are supported by carriages on rollers; while others use conduction or convection to convey the temperature of the dryer surface to the sensing element.

1. *Sliding contact pyrometer.* Sliding contact pyrometers consist of a metal strip that slides on the dryer surface. A thermocouple (usually type K) is welded on the side that does not contact the dryer. Temperature readings are generally shown on a battery-operated digital display.

The large area of the metal strip reduces frictional effects of the strip sliding on the dryer at high surface speeds. Some units have sensors mounted in small frames that also contact the dryer surface and control contact pressure of the metal strip on the dryer to minimize frictional effects and improve reliability.

Some commercially available sensors are mounted on carriages with rollers. Most of these roller assemblies are limited to surface speeds less than 300 mpm (980 fpm). Generally, the added weight of the carriages makes these units more difficult to use. They are generally used on slow speed dryers that have open access.

2. *Direct contact thermocouple.* Commercial units are also available with the dissimilar metal thermocouple elements formed into a strip that contact the moving surface directly and are mounted to a support block or a carriage with rollers. At speeds greater than 300 mpm (980 fpm), these sensor readings are often affected by frictional effects.
3. *Boundary layer measurement sensors.* Dryer surface temperatures can also be determined by measuring the temperature of the boundary layer of the air next to the dryer surface. This approach requires that the air next to the dryer be isolated from external air influences. These devices typically enclose a sensor with a low thermal mass, such as a fine wire thermocouple or an RTD element, in an insulated enclosure that is in contact with the dryer.

Contact pyrometers are generally made and used by experienced technicians. They are frequently used to conduct full CD temperature profile surveys. Special equipment is needed to safely hold the devices in place on the dryer and to traverse them across the machine width to obtain a CD profile.

One instrument of this type has a Teflon carriage that slides directly on the dryer surface. A similar unit uses a thermistor sensor to measure the boundary layer air temperature and has the sensor mounted in a carriage with rollers. Most units of this type that are commercially available have slow responses and are fragile. As a result, they have not proven to be popular for measurement of dryer surface temperatures.

B. Infrared pyrometers. The only truly non-contact temperature measurement system is the infrared pyrometer. Infrared radiation from the dryer surface is detected by an infrared sensor. The instrument uses the signal to compute surface temperature. Emissivity properties of the surface are entered as an input to the instrument. Infrared sensors provide unreliable values and are not recommended for dryer surface temperature applications.

The most common types of infrared sensors are hand-held guns. The sensor is simply aimed at the surface to be measured and temperature is automatically displayed.

Infrared sensors have the distinct advantage of not having to contact the dryer surface. A direct unobstructed view of the surface is needed. However, one of the primary disadvantages is the variable emissivity of dryer surface. Errors of up to 50°C in surface temperatures can result from variations in the dryer surface emissivity. Also, some gun types read a “cone” and not a small area, unless the unit is close to the dryer surface.

Infrared techniques can provide accurate temperature measurements in some situations and erroneous readings in others. Since emissivity must be entered for each dryer, emissivity must be relatively constant if the indicated temperature profile is to be accurate. A typical dryer with a shiny surface, however, has low emissivity that can change drastically with a buildup of pulp, coating, or filler on the surface. Reflectance of lighting from shiny surfaces is also detected by infrared instruments, producing false readings.

Inaccurate readings can also occur when dryer pockets have high humidities. When steam vapor is present, dryer pockets are not optically clear and infrared sensors measure temperature of the condensing water vapor, which is at a lower temperature than the dryer surface. A cool infrared instrument, brought close to a dryer with a high humidity pocket, can have condensation on its lens and will report condensation temperatures instead of the dryer surface, which it can no longer “see.”

Despite these sources of error, hand-held infrared guns have proven useful to quickly identify dryers that have filled with condensate by measuring temperature of dryer heads and/or the sheet. High humidity and emissivity variations are not significant variables for dryer heads and a dryer head with low temperature is an indication of a fully water-filled dryer. However, a dryer that is filling with condensate, but not yet completely filled, may not have a cool head. Note that emissivity variations can produce false temperature readings if heads are painted or severely stained with lubricant.

Situations where infrared techniques have been successfully used include paper machines where dryers have uniform surface conditions and pockets have good optical clarity.

Infrared thermography

Infrared thermography is a technology frequently used to monitor large areas for hot spots such as in electrical control panels and switchgear. These systems use infrared cameras to display entire viewed images as pictures, and different temperatures are displayed in different colors. Temperature streaks can be readily identified. A limitation of this device is that it cannot distinguish between temperature variations and emissivity variations.

Applications of this technology in the paper industry have included monitoring of Yankee dryer temperature profiles and cross-direction uniformity of fabric profiles. This approach has also been found useful in monitoring the profile of the sheet throughout the machine, from the fourdrinier and through the press and dryer sections and to the reel. Dry-end cross-machine variations can be traced to the machine direction position at which the variations first occur. This helps identify such sources of profile non-uniformity as poor steam shower performance, moisture streaks in fabrics, dryer grooves, and basis weight variation.

Interpretation of data

Although accuracy and repeatability of temperature measurements are important criteria for selecting an instrument for measuring dryer surface temperatures, other factors must be understood to properly evaluate measured temperatures. Difference between dryer surface temperatures and steam saturation temperatures is influenced by many factors. Often only relative temperature differences between dryers are needed to determine dryer performance. An example of a graphical plot of machine-direction surface temperatures is shown in Figure 1. This example is for a machine that has four dryer sections operating at different steam pressures. Saturation temperature of the steam in each section is shown on the graph.

Cross machine temperature profiles provide another indication of heat transfer performance. A typical cross-machine profile with marginal dryer drainage is shown in Figure 2. The dryer surface is hotter near the edges as a