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 and good thermal contact with the sheet 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 siphon 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. Ensure that the measuring sensor cables are not wrapped around your arms or feet. Beware of thermal and slip hazards around the dryer section.

Be aware of, and closely follow any overriding local mill safety regulations and permitting required to perform any diagnostics.
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 resulting drying rate). Low dryer surface temperature can be produced by either high heat transfer rates (good for drying) or high resistance to heat transfer (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. It is possible for very high pocket humidities to limit the heat flow to the sheet by restricting evaporation, in which case dryer surface temperatures may be higher. On the other hand, well ventilated pockets allow for efficient evaporation, which in turn increases the heat flow, thus cooling the dryer surface.

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 below.

![Graphical presentation of dryer temperature survey results](image)

Fig. 1. Graphical presentation of dryer temperature survey results.

Suggestions for interpreting the data are given at the end of this technical information paper. Additional data and measurements may include measurement of sheet temperatures and pocket humidities; these are discussed in TAPPI TIP 0404-33.²

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 may include measurements of complete cross-machine direction temperature profiles of several dryer cylinders.

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 siphon 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 and non-contacting (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. Note that 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 m/min (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 to the dryer surfaces.

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 m/min (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.

   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.

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.

B. Infrared pyrometers. The only truly non-contact temperature measurement system available today is an infrared pyrometer. Infrared radiation from the dryer surface is detected by an infrared sensor. The instrument uses the sensor signal to compute surface temperature. Emissivity properties of the surface are entered as an input to the instrument. Infrared sensors provide unreliable values due to challenges posed by shiny, moving surfaces and large variations in the dryer surface emissivity, and are therefore not recommended for dryer surface temperature applications.

Despite the high potential for surface temperature measurement 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.

In some rare cases the dryer head temperature trend follows the surface temperature quite closely. This has been evidenced on slow speed machines with poor contact between the sheet and the dryers, such as cylinder dried pulp or heavy board, with no dryer felts.

C. **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 thermography and imaging systems to display entire viewed images as pictures, and different temperatures. Temperatures may be displayed in many ways (as lines of constant temperature, as black and white with temperature changes as shades of gray, or different temperatures may be displayed in different colors). *A key limitation of infrared thermography 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, as discussed in TAPPI TIP 0404-57.4

**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 presented in Figure 1, shown earlier in this document. 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.

![Fig. 2. Typical CD temperature profile with marginal dryer drainage.](image)

The dryer surface is hotter near the edges as a result of condensate turbulence near the dryer heads and cooler in the center because of a thick, stagnant condensate layer. This typical “smile” surface temperature profile results in a
“frown” sheet moisture profile since less heat transfer occurs through the thick condensate layers at the center of the dryers. Additional information on troubleshooting cross-machine direction moisture profile problems is available in TAPPI TIP 0404-57.4

Typical areas of consideration for dryer surface temperature data interpretation are summarized in the following.

A. **Steam temperature.** Higher steam pressures generally produce higher dryer surface temperatures. It is the temperature difference between the saturation temperature of the steam and the dryer surface that provides the driving force for heat transfer from the steam through the condensate layer and dryer shell. The plot of surface temperatures should include a plot of corresponding steam saturation temperatures. A steam pressure increase that is not accompanied by a dryer surface temperature increase needs to be investigated. In Figure 1, dryer surface temperatures increase with steam pressure increases at dryers 10, 16, and 36.

B. **Sensible heating.** Sensible heat is the heat that is transferred to the sheet and stored in the sheet in the process of raising its temperature without evaporating moisture. The first several dryers in a higher pressure section typically have lower dryer surface temperatures than the following dryers because the sheet is not yet up to temperature. The first 4–6 dryers that provide the initial warm-up of the sheet will show low surface temperatures that are gradually increasing. Figure 1 shows low surface temperatures and high steam-to-surface temperature differences for top unorun dryers 1, 3, 5, 7, and 9.

C. **Condensate layer.** In dryers with rimming condensate, the major resistance to heat transfer is often the condensate layer. The thermal conductivity of condensate is 70 times less than that of cast iron. Thus a 3 mm condensate layer has a thermal resistance that is 5 to 10 times larger than the entire dryer shell. An unusually low dryer surface temperature is often an indication that the condensate layer in the dryer is too thick.

Dryers that have significant temperature variations or are cooler than their adjacent dryers should have siphon clearances checked.

Dryer 15 is flooded in Figure 1 and drainage is marginal in dryers 18, 28, 32, 34, 40, and 42. Consistent top-to-bottom dryer temperature variation can be an indication of undersized condensate piping or low dryer fabric tension. A dryer following a cooler dryer may also have a slightly lower temperature because it must reheat the sheet.

The top graph in Figure 3 shows the cross-machine temperature profile of a dryer with dual stationary siphons (one stationary siphon on each end of the dryer) and problems draining from the drive side. The bottom plot shows the same dryer with proper siphon clearances.

![Fig. 3. Typical CD temperature profile with drive side siphon problem.](image)

D. **Machine speeds.** When machine speeds are below full rimming, heat transfer occurs primarily by mixing and is very effective. As machine speeds go above the 300–400 m/min (980-1,300 fpm) range for 1.5...
m (5 ft) diameter dryers, condensate begins to rim. As speeds increase further, turbulent action of condensate is reduced and heat transfer proceeds primarily by conduction through the condensate layer. Overall resistance to heat transfer increases and the steam-to-shell temperature difference increases.

When comparing dryer surface temperature data for machines operating at different speeds, dependence of surface temperature on machine speeds needs to be considered.

**E. Bottom unorun dryers.** On unorun dryers, the wet sheet does not directly contact the surface of the bottom dryers and there is little heat transfer to the sheet. At the same time, the sheet is in direct contact with the top unorun dryers with a large wrap angle and there is a large amount of heat transfer and the dryer shell will be cooled significantly.

In such dryer sections, dryer temperatures alternate between low values (for top dryers that are cooled by the sheet) and higher values (for bottom dryers that do not contact the sheet). This is a normal characteristic of unorun dryer sections.

The effects of unorun felting are evident for the first 10 dryers in Figure 1. Note that it is normally recommended that steam be disconnected from bottom unorun dryers, as these dryers do not contribute much to drying of the sheet.

**F. Fabric wrap and fabric tension.** Proper dryer fabric tension minimizes the insulating air boundary layer between the sheet and the dryer, increases thermal contact between the dryer and the sheet, and increases heat transfer and condensing rates.

When good contact is obtained between the sheet and the dryer, heat transfer is maximized and temperature difference is greatest. Higher surface temperatures result from those dryers that do not have fabrics and for other dryers with low sheet wrap, such as first or last dryers in a section. Higher surface temperatures on all of the dryers with the same fabric can indicate low fabric tension.

In Figure 1, dryers 17, 35 and 36 are at the beginning and end of fabric runs, have low fabric wrap, and are hotter than neighboring dryers because of reduced heat transfer.

Figure 4 shows the effects of dryer felting on surface temperatures. The top plot is the profile of an unfelted dryer while the bottom plot is of a felted dryer in the same section.

![Fig. 4. Typical effect of felting on dryer surface temperature; felted vs. unfelted dryer.](image-url)
The effects of felting change with sheet moisture and basis weight. Figure 5 shows machine-direction temperatures of a linerboard machine with top and bottom fabrics in the first two sections and only top felts in the remaining groups.

A distinct top-to-bottom temperature difference is evident in the third and fourth sections with the unfelted bottom dryers being hotter than the top dryers.

There is, on the other hand, almost no difference between top and bottom dryers at the dry end of the machine, where the moisture content is lower. A drier and stronger sheet typically has tighter draws and better contact with the dryer surfaces.

Figure 6 shows the same machine measured on a heavier grade. No top-to-bottom temperature difference is seen, even in the third and fourth sections.

Lower machine speeds and cascading condensate result in good heat transfer for both top and bottom dryers.

Poor fabric tension can also affect cross-machine profiles. The top plot in the following Figure 7 shows the cross-machine profile of a dryer that had problems with the fabric tension mechanism, and the actual tension was lower than indicated on the displays.
Correcting the problems with the tensioning mechanism, and increasing the fabric tension as required for the production speed, resulted in an improved profile (at a lower steam pressure) as shown in the bottom plot.

Felt tension may also be skewed due to dryer and/or felt roll misalignment.

G. Dryer bars. Dryer bars installed inside dryers increase turbulence in a rimming condensate layer and increase heat transfer. This reduces the temperature difference between steam and the dryer surface.

The application of dryer bars is described in detail in TIP 0404-35.3

Figure 8 shows an average cross-machine dryer surface temperature profile of a high-speed machine without dryer bars.
Figure 9 shows the profile of the same dryers (at a lower steam pressure) after bars were installed.

This machine was able to increase production rates by 18% after the bars were installed.

Some machines utilize partial-width dryer bars to improve sheet moisture profiles. Dryers with partial-width bars can have large changes in CD temperature profile, as shown in Figure 10. Note that profiling dryer bars are no longer a recommended application of dryer bar technology.

H. Sheet moisture. Dryer surface temperatures tend to remain fairly constant as long as there is sufficient moisture in the paper to absorb heat from the dryers. As the paper web approaches the end of the dryer section, it has little moisture and dryer heat load decreases. This phenomenon can be identified by a progressive increase in dryer surface temperatures near the dry end of the machine.

A significant rise in surface temperatures of dryers at the dry end can indicate a condition of over-drying the paper. This is normal behavior and does not indicate any problem with the dryers. Figure 1 demonstrates this behavior from dryers 41 through 51.
I. **Superheated steam.** The added quantity of heat available in steam due to the addition of superheat is a relatively small portion of the total heat content of the steam. Superheated steam must be cooled to its saturation temperature before it can condense and release most of its heat.

Dryers with superheated steam do not have increased dryer surface temperatures. In dryers that have steam with some superheat, the dryer surface temperature should be compared to the saturation temperature that corresponds to the dryer steam pressure rather than to the superheat steam temperature.

Excessive superheat can result in premature steam joint failure from high temperature and can reduce the mass flow of steam through piping and supply valves since superheated steam has higher specific volume than saturated steam.

J. **Non-condensable gases.** Accumulation of non-condensable gases inside dryers can cause a significant reduction in dryer surface temperatures by decreasing partial pressure of steam and retarding flow of steam to condensing surfaces inside the dryer.

Accumulation generally occurs in wider dryers when the steam supply and condensate extraction are on the same side of the dryer. A difference in dryer surface temperatures between the front side and the back side often indicates such a problem. Typically, it is the front side that is cooler because non-condensable gases have accumulated there.

Non-condensable gases (NCGs) can be the result of poor boiler operation, rotary joints and piping leaks in dryers that are operating under a vacuum, or inadequate purging of air following a shutdown. Thermocompressor recirculation systems typically require a way to purge NCGs from the otherwise closed loop circuits.

K. **Dryer alignment.** Long-term settling of dryer baseplates can eventually cause one side of the dryers to be lower than the other side. Settling usually occurs on the back side (due to weight of dryer gears) but may also be on the tending side. This causes a slightly thicker layer of condensate to accumulate in the low end, which in turn decreases dryer surface temperature. Misalignment may also cause non-uniform felt tension.

A gradual drop in temperature across the width, which is not otherwise explained, suggests a possible problem with dryer alignment. Figure 11 shows an example profile with tending side settling.

![Fig. 11. Effect of dryer alignment on dryer surface temperature](image)

L. **Differential pressure.** Proper differential pressure is important to evacuate condensate from dryers and maintain high and uniform dryer surface temperatures. Insufficient differential pressure with rotary siphons results in a thick condensate layer, low surface temperatures, and poor profiles. Excessive differential pressure will produce excessive blow-through steam that will increase pressure losses, erode siphon components, and result in a waste of energy.
Figure 12 shows cross-machine profiles of a machine operating with insufficient differential pressure. Increasing differentials from 20 to 35 kPa (3 to 5 psi) increased temperatures and improved profiles slightly. Later increasing differentials to 50 kPa (7 psi) further improved dryer evacuation.

![Fig. 12. Effect of differential pressure on dryer surface temperature.]

Note that optimal differential pressures are typically 3-5 psi for stationary siphons and vary with machine speed with rotary siphons usually between 3-12 psi. It is not always true that increased differential results in improved dryer evacuation. Among all dryer steam section measurements typically taken, differential pressures are the one most often found to be incorrect. Accurate indication of differential pressures is essential to optimal operation. For further discussion on differential pressures, please see TIP 0404-311.

M. Dryer grooves. Some older dryers were machined with shallow grooves near one or both ends for installation of rotary or stationary siphons. Other dryers have had grooves worn in them by stationary siphons that contacted the shell or balance weights that have worn grooves in the shell. Accumulation of condensate in these grooves can cause a significant reduction in heat transfer producing cold bands on the dryers.

The siphons must be properly adjusted and functional, or else the grooves must be filled or equipped with bars that provide turbulence in the condensate layer also in the grooves. Figure 13 shows a cross-machine profile from a machine with center-mounted rotating siphons and grooves at the tending and drive side edges.

![Fig. 13. Effect of internal grooves on surface temperature]

Note that wet streaks in the sheet can also produce these same indications. Wet end surveys with IR thermography can distinguish between dryer groove and wet streak temperature variations.

N. Dryer surface condition. The surface condition of a dryer affects the temperature readings. Wet end dryers sometimes have a build-up of fiber and filler on their surfaces. This fiber coating will generate frictional heating of a sliding contact pyrometer to produce a high and inaccurate surface temperature reading.
as well as retarding the transfer of heat to the sheet. In some cases the surface condition may lead to poor contact between the sensor and the dryer, and therefore provide temperature readings that are too low. Dryers with coated surfaces should be identified during a temperature survey and this condition taken into account when interpreting the data.

**O. Furnish.** Top-to-bottom temperature differences can indicate significant differences in properties between the wire side and felt side of the sheet. This trend has been observed on linerboard machines with multiple sheet layers.

**P. Unusual problems.** Some machines exhibit dryer temperature profiles that are not easily explained. Figure 14 shows an example of an unexplained profile. The top and bottom plots show profile measurements of the same dryer taken one year apart.

![Fig. 14. Example of an unexplainable temperature profile issue.](image)

Figure 15 shows profiles of another dryer on the same machine that had dryer bars installed between the two sets of measurements. The bars were able to correct some, but not all, of the unusual temperature profile.

![Fig. 15. Unusual surface temperature profile not totally corrected by installation of dryer bars](image)

Possible root causes of this profile problem include non-uniform casting of the dryer shells or non-uniform moisture profiles coming from the press section.
Sometimes the dryer surface temperature profile can mirror the moisture profile of the sheet. Theoretically this could occur in transitional areas such as when the sheet is brought to evaporation temperature and evaporation begins; when most of the surface water has been evaporated; when the falling rate zone begins; or right after a rewet shower, size press, or coater.

**Instrument suppliers**

TAPPI TIP 0404-33\(^2\) contains an extensive Supplier Directory for instrumentation that can be used for monitoring dryer section performance.\(^1\) Suppliers of contact pyrometers include Swema (TMI), Solomat (Lumidor), and EDL. Infrared sensor and camera suppliers include Ametek, Flir, Fluke (Raytek), LumaSense (Mikron) and Omega.

**Keywords**

Dryers, Temperature, Pyrometry

**Additional Information**

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**References**

1. TAPPI TIP 0404-31 “Recommended dryer differential pressures”
2. TAPPI TIP 0404-33 “Dryer section performance monitoring”
3. TAPPI TIP 0404-35 “Application of dryer bars”
4. TAPPI TIP 0404-57 “Troubleshooting cross-machine direction moisture profile problems”

\(^1\) Suppliers wishing to be added or removed from the supplier directory should inform the Standards Department at TAPPI, in writing, referring to TAPPI 0404-33.