THE MONITORING AND CONTROL OF SHEET TEMPERATURES AT THE WET END

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ABSTRACT

This paper discusses the impact of sheet temperatures on water removal at the wet end of the paper machine, hence moisture at the reel, with emphasis on the use of steam showers to control both. The performance of non-profiling and profiling steam showers is documented with temperature data collected with thermocouples, infrared temperature guns and a strip chart recorder. The use of sheet temperatures as a tool to monitor and troubleshoot the performance of steam showers is also addressed.

Introduction

The precise control of sheet temperature is the key to controlling water removal at the wet end. This paper focuses on measuring those temperatures and relating their effects to moisture at the reel.

Relation of Sheet Temperature to Water Removal

The familiar viscosity curve of figure 1 illustrates why it is easier to remove water from a hot sheet than a cold sheet especially at lower temperatures.

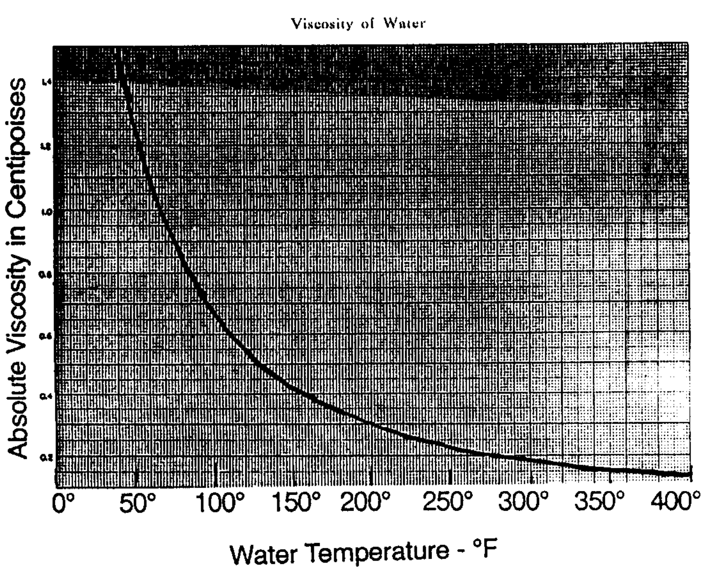

Fig. 1 - Viscosity of Water vs. Temperature.

The most common way to heat the sheet is to apply steam with a steam shower at the wet end of the paper machine. To check the effect of the steam shower, abruptly turn it off and see what happens. If the sheet immediately gets wet and widens out on the reel, you know that the steam shower upstream is responsible.

The best method of evaluating a steam shower's performance is to monitor moisture downstream. Evaluations are simplified if the machine's computer can be set up to automatically control speed to maintain a specific moisture target at the reel as the amount of steam supplied to the steam shower is changed.

Following is a good example of the effect one fourdrinier steam shower had on a fluff pulp machine running under speed optimization control. As part of the start-up evaluation we wanted to determine optimum steam flows. The machine was producing about 33 tonnes/hr of fluff pulp at a speed of 595 fpm (180 m/min.). The profiling steam shower was operating at a flow rate of 0.20 kg of steam per kg of pulp produced, which in this case, was 14,500 lbs/hr (6,577 kg/hr) supplied at a pressure of 15 psi (103 kPa).

Steam supply pressure to the steam shower was cut back 2 psi (14 kPa) at a time, with about twenty minutes allowed between adjustments for the machine to automatically slow down. Among other data collected, figure 2 illustrates that machine speed slowed 11% as steam flow was reduced. The amount of steam (heat) first added to the sheet had the greatest impact.

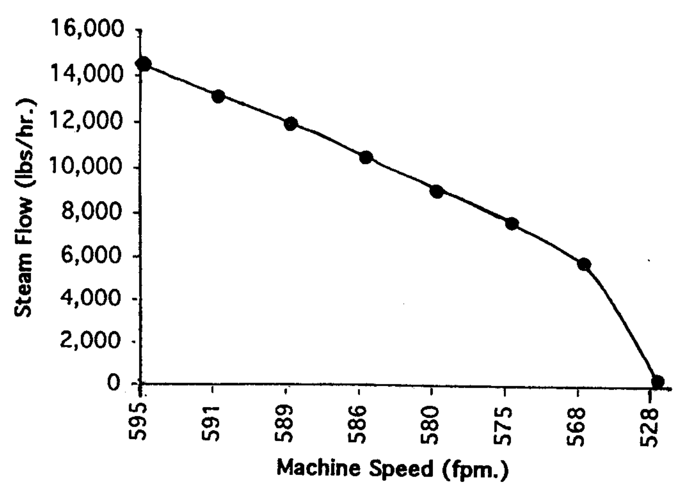

Fig. 2 - Under speed optimization control, the machine automatically slowed down as steam input to a profiling steam shower was reduced.

The curves of figure 3 were collected soon after start-up of a profiling steam shower on the fourdrinier of a different pulp machine. In this trial a single 6" (152 mm) wide compartment on the profiling steam shower was adjusted in six increments from 0% open to 100% open. The moisture scanner at the reel was set on single point in line with the compartment. In this case, in-line sheet surface temperature just downstream increased 78°F (43°C) and reel moisture dropped 3.5%.

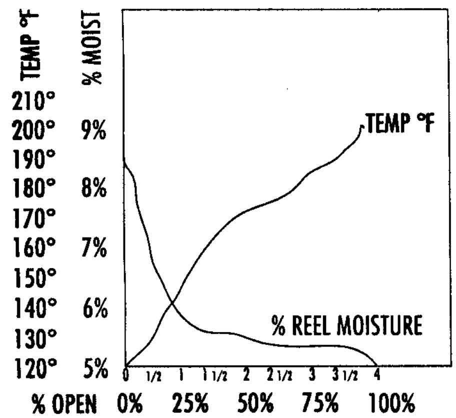

Fig. 3 - Effect on sheet temperature and moisture at the reel as a single compartment of a profiling steam shower was adjusted from full closed to full open. The moisture curve is very similar to that of water viscosity vs. temperature.

As in figure 2 the amount of steam (heat) first applied to the sheet made the biggest difference. Note the similarity between the moisture curve and that of water viscosity.

Infrared Temperature Guns

Given the importance of sheet temperature on water removal, it makes sense for all machine operators, particularly those who lack moisture scanners, to be aware of sheet temperatures at the wet end.

The simplest and least expensive tool the mill can use for measuring sheet temperatures, hence the performance of a steam shower, is an infrared temperature gun. They come in all shapes, sizes, sophistications and costs.

If the temperature gun is equipped with a millivolt output jack, the signal can be sent to a strip chart recorder so CD temperature profiles or machine direction sheet temperature fluctuations can be documented. Approximate CD profiles can be obtained by walking at a steady rate across a catwalk from the tending side of the machine to the drive side, then back to the front again while pointing the gun at the sheet. Valid CD profiles should end up as mirror images.

Depending on accessibility and configuration of the press section, CD temperature profiles can be shot before and after each press nip to clearly identify sources that cool the sheet such as a suction couch or cold felts in a press nip. Monitoring temperatures of both surfaces of the sheet and felts can also help identify the direction in which water is being removed from the web.

Temperature Variations Resulting from Poorly Designed or Incorrectly Operated Steam Showers

The non-uniform CD sheet temperature profiles of figure 4 were shot after the couch and after the first press on a pulp machine with a non-profiling steam shower installed over the last flat boxes on the fourdrinier. This particular model steam shower is notorious for delivering more steam to the edges of the sheet than to the middle.

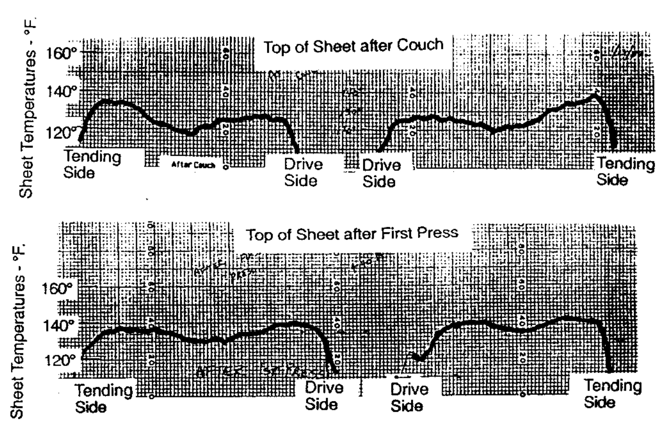

Fig. 4 - CD temperature profiles with mirror images illustrate non-uniform sheet temperatures resulting from a poorly designed non-profiling steam shower.

Figure 5 illustrates sheet temperature variability in the machine direction downstream of a different model non-profiling steam shower that was installed on a different pulp machine.

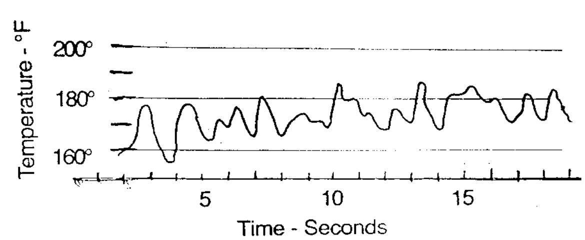

Fig. 5 - Sheet temperature variation in the machine direction is often caused by the mixing in of air with high velocity turbulent steam exiting a poorly designed steam shower.

The problem with these two steam showers (both now out of production) and many homemade showers is that steam blasts from them at an uncontrolled high velocity. This creates turbulence and mixes air with the steam.

Both air and steam are gases. However, unlike air, pure steam contains 1000 or so valuable btu's which are released when it condenses. When a turbulent mixture of air and pure steam is pulled into the sheet by vacuum below, variable temperatures downstream result because the air plugs up the pores in the sheet and prevents the steam from being pulled in.

Other detrimental effects from poorly designed steam showers include excessive noise, danger to the operators passing by on nearby catwalks, potential disruption of the sheet surface and inefficient steam usage.

You can often identify turbulence exiting a steam shower with a thermocouple. Figure 6 is an example of turbulence around two homemade steam showers installed over the last three suction boxes on the fourdrinier. To adequately saturate the vacuum boxes below with steam, a very high flow rate of 30,000 lbs/hr (13,600 kg/hr) or 0.35 lbs steam per lb. fiber produced was required.

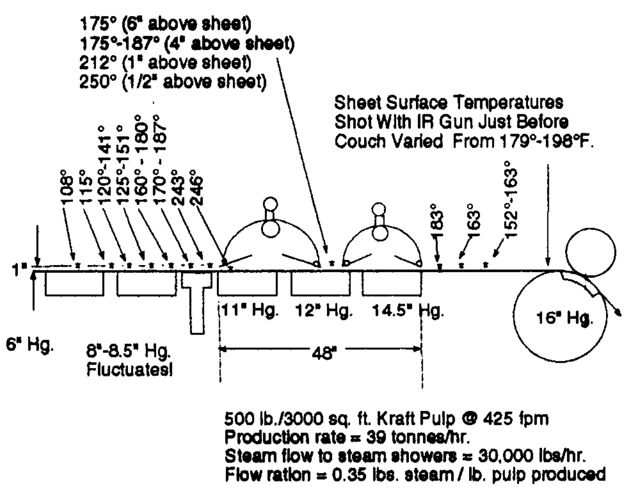

Fig. 6 - Temperatures recorded with a thermocouple illustrate variable temperatures resulting from high velocity steam exiting two homemade steam showers.

At these high flow rates, a mixture of transparent superheated steam, air and resulting white fog was apparent upstream and downstream of the steam showers, resulting in variable temperatures.

A new 48" (1220 mm) wide profiling steam shower for this machine is designed to deliver only as much non-turbulent steam to the sheet as the vacuum boxes below can pull in. It will be far more efficient.

Temperature Variations Resulting from Lower than Recommended Steam Flows

Non-uniform machine direction sheet temperatures can also result downstream from a steam shower which is not fed with enough steam.

Figure 7 is a diagram of sheet temperatures shot about 2 ft. in from from the tending side of the machine with an IR gun. The machine had a profiling steam shower on the fourdrinier and non-profiling, non-turbulent steam shower in the first suction press nip.

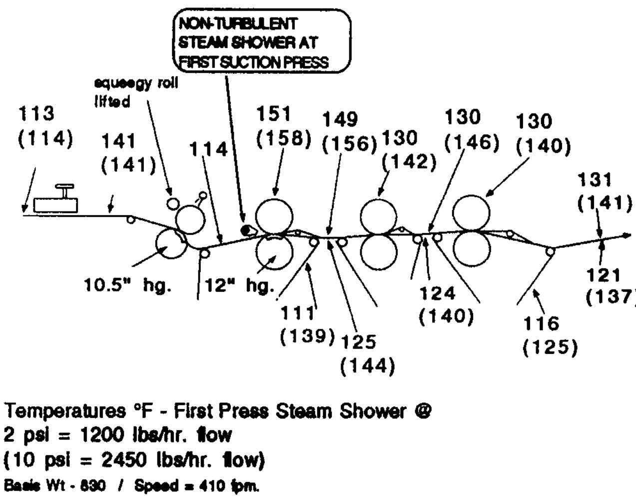

Fig. 7 - Sheet temperatures measured from the tending side on a pulp machine with steam showers on the fourdrinier and at the first suction press.

The non-turbulent steam shower at the first press was being supplied with steam flow of only 1200 lbs/hr (545 kg/hr), instead of the recommended 2450 lbs/hr (1110 kg/hr). At this low flow rate, the suction box of the press was sucking a mixture of pure non-turbulent steam and air into the sheet causing sheet surface temperatures after the first press to fluctuate from 146°F - 165°F (63°-74°C) in the machine direction. The resulting white fog, which is actually condensed steam, between the non-turbulent steam shower and the press nip shows up in figure 8.

When steam flow to the non-turbulent steamer was increased to the recommended level, the fog in the nip was replaced by pure, transparent steam and machine direction sheet temperature fluctuations downstream disappeared. Furthermore, as indicated by the temperatures in parentheses in figure 7, average sheet temperatures entering the dryer increased about 13°F (8°C) and moisture at the reel dropped 1.6%. A 5% reduction in machine direction moisture variability was noted on back-to-back jumbo rolls before and after increasing steam flow to the recommended level.

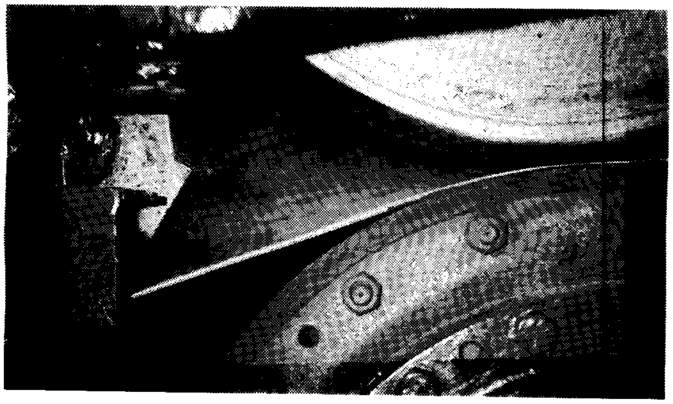

Fig. 8 - Visible white "fog", which is contaminated steam, is seen in a suction press nip with inadequate steam flow from a steam shower.

Incidentally, the 25°F (14°C) sheet surface temperature drop over the couch was later corrected by installing another non-turbulent steam shower at the outgoing nip of the couch-lumpbreaker.

Figure 9 illustrates temperatures measured with a thermocouple carefully inserted between a correctly operated non-turbulent steam shower and the nip of a suction press. An "air-steam interface" is often apparent where pure steam above 212°F (100°C) meets air and condenses into white visible fog with a temperature of less than 212°F (100°C). The location of the interface can be moved upstream or downstream by regulating steam flow.

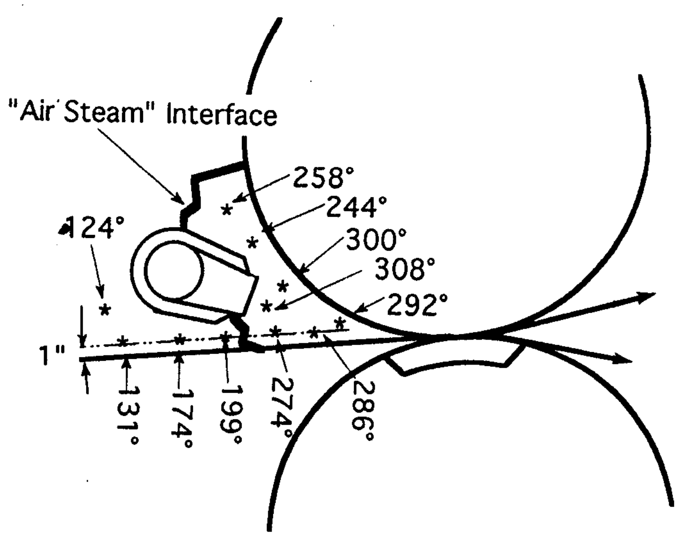

Fig. 9 - Temperatures-F. measured with a thermocouple in a suction press nip illustrate where pure, superheated steam above meets air and condenses into visible "fog".

Effect of a Profiling Steam Shower on Sheet Temperature and Moisture Downstream

The purpose of any profiling steam shower is to apply more steam to wet areas of the sheet and less to dry areas.

Some machines going all out for production will operate their profiling steam showers with all compartments wide open resulting in uniform temperature profiles downstream.

Others might adjust their profiling steam shower to heat chronically wet edges (figure 10).

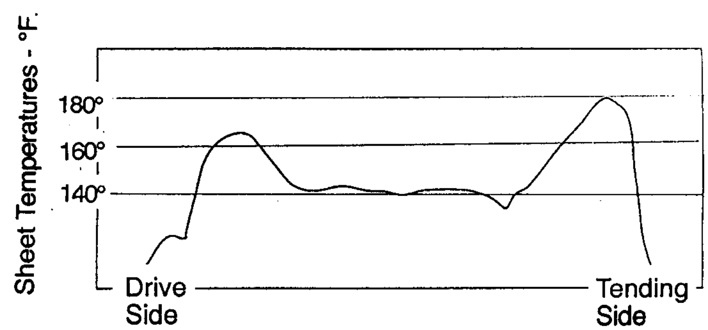

Fig. 10 - Machines with chronic wet edges can adjust a profiling steam shower to deliver more steam, hence heat, to the edges of the sheet than center.

For precise temperature and moisture control with a profiling steam shower, particularly when installed over a suction device, air must be allowed to enter the sheet where you do not want to apply steam otherwise the steam will "couple" that is spread, in the CD from open compartments to adjacent closed compartments. CD temperature profiles are very valuable in documenting the degree of coupling from a profiling steam shower.

For accurate heating of wet streaks, the compartments of a profiling steam shower must line up with the printouts from a moisture sensor at the reel. Such "mapping" is especially important if the profiling steam shower is automatically controlled by computer. Evaluations are simplified if the profiling steam shower's compartment settings show up on the same CRT display as the moisture profile.

The curves of figure 11 and figure 12 illustrate how adjusting a single compartment of a profiling steam shower on the fourdrinier of a fluff pulp machine effected sheet temperatures and moistures downstream.

The top curve of figure 11 represents moisture profile at the reel, the middle curve is the temperature of the bottom of the sheet entering the dryer and the bottom curve compartment settings. Sheet temperatures entering the dryer follow the compartment settings.

Soon after startup, to confirm that the moisture sensor at the reel was centered and that the compartments of the profiling steam shower lined up with slice positions labeled on their printouts, we abruptly shut off a single 6" wide (152 mm) compartment - #22 - right in the middle of the sheet. This abrupt "bump" caused a 2.2% increase in air dry moisture at the reel and a precise 10°F temperature dip directly in line (figure 12). The test confirmed that indeed, the compartments of the profiling steam shower lined up with the scanner.

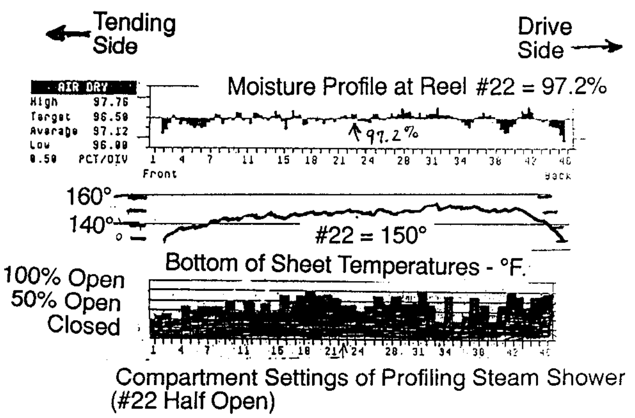

Fig. 11 - Moisture printout, temperature profile, and profiling steam shower compartment settings on a fluff pulp machine.

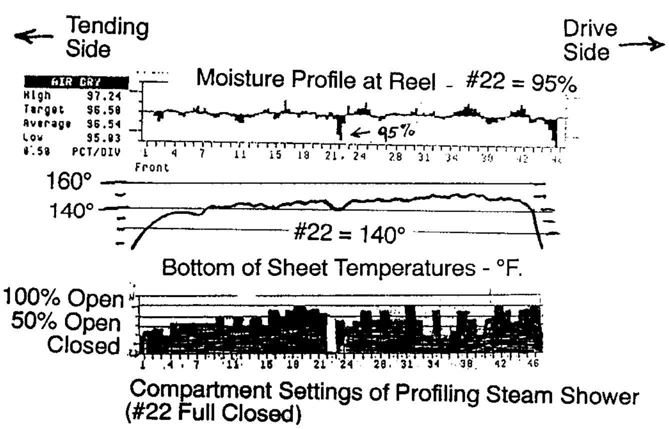

Fig. 12 - To confirm that the compartments of the profiling steam shower of Figure #11 precisely lined up with the CRT screen and printouts, a single 6" (152 mm) wide compartment (#22) was abruptly bumped from half open to full closed. Sheet temperature entering the dryer in line dropped 10°F (5°C) and moisture at the reel increased 2.2% in line.

The three moisture printouts in Figure 13 are from a different fluff pulp machine with a similar press section configuration. We picked out the wettest spot of the sheet and bumped the 6" (152 mm) wide compartment in line with it from about 60% open to full closed. Moisture at the reel increased from 6.9% to 8.7%. When the compartment was fully opened, moisture in line dropped to 4.4% for a total change of 4.3%. Sheet temperatures entering the dryer on this machine also changed 10°F (6°C).

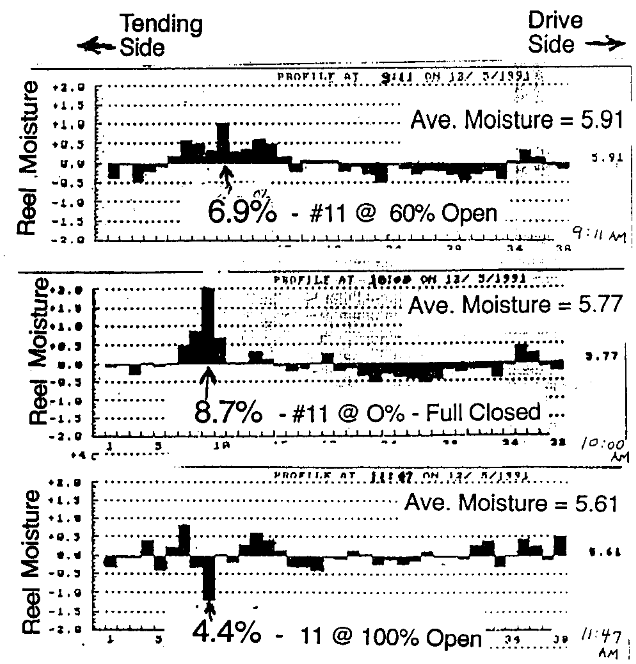

Fig. 13 - As part of a startup evaluation, adjusting a single compartment of a fourdrinier profiling steam shower from full open to full closed caused moisture at the reel in line to increase 4.3%.

Sheet Temperature Monitoring as an Evaluation Tool

There are often too many variables involved on a specific paper machine to categorically guarantee that a steam shower will cause X temperature increase at the wet end, Y moisture decrease at the reel and Z dryer limited production increase.

A good way to identify a steam shower's potential on a dryer limited machine is to use an IR gun to check for sheet temperature drops as it passes over a suction couch or through a press nip. It is often possible to test the benefit of a steam shower in such locations by blowing smoke or powder over the sheet. If the smoke is aggressively pulled into the sheet, there is marvelous potential for replacing air with steam to heat instead of cool the sheet.

If the location is questionable, trials with a small trial steam shower may be warranted before committing to a full sized unit. Particularly on machines lacking moisture scanners at the reel, wet end sheet temperature documentation during trials is very useful.

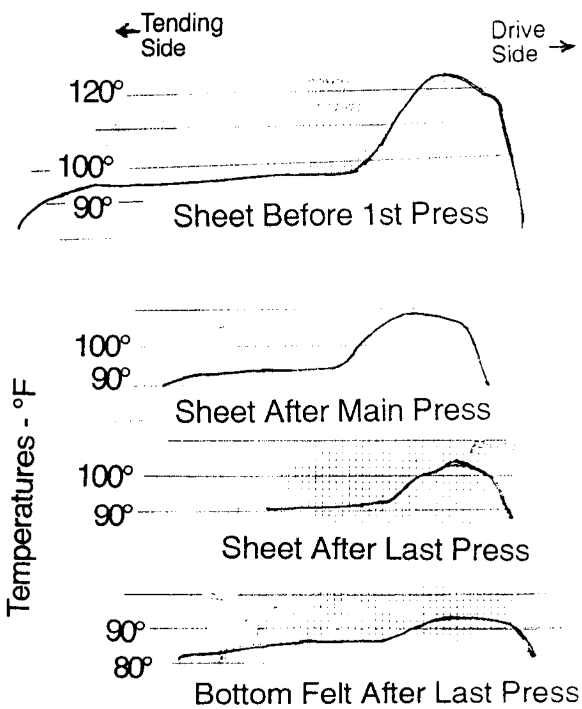

Fig. 14 - A series of CD temperature profiles in the press section document the performance of a trial steam shower positioned over the edge of the sheet upstream.

The set of CD temperature profiles in figure 14 were shot from four locations in the press section of a multi-vat board machine. We were testing a 2 ft. wide trial steam shower over the back edge of the sheet at the drive side. The effect of the steam shower on sheet temperatures downstream was obvious. Since the sheet temperature increases on this machine were similar to those achieved downstream from full sized steam showers on similar machines we were able to confidently guarantee the installation.

CD Temperature Profiles as a Trouble Shooting Tool

Temperature profiles can be used as a diagnostic tool. They can pinpoint problems such as a faulty headbox, poorly ground press roll, plugged felt or needle shower, plugged suction box or problems with a steam shower upstream.

Following is an example of a pulp machine where one of the actuators on their newly installed profiling steam shower had failed in the full closed position. An 8.4% wet streak at the reel in line with compartment #15 was limiting machine speed. Figure 15 illustrates the wet streak at the reel and a temperature dip in the CD temperature profile shot of the bottom of the sheet entering the dryer.

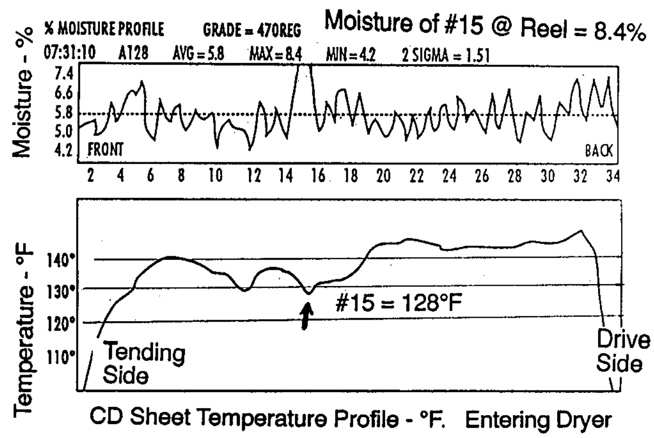

Fig. 15 - A cold streak in the temperature profile on this machine confirmed that a non-functioning actuator on their profiling steam shower was to blame for the wet streak in line with slice #15.

Here is what happened. During installation of the steam shower an "O" ring had fallen out of their pneumatic quick disconnect plate. The resulting air leak prevented the actuator from delivering steam to that one compartment.

When the air tubing to the actuator was bypassed around the missing "O" ring the compartment was adjusted to 40% open. Sheet temperatures in line immediately increased from 128°F (53°C) to 142°F (61°C) and the wet streak at the reel was reduced from 8.1 to 6.5% (figure 16).

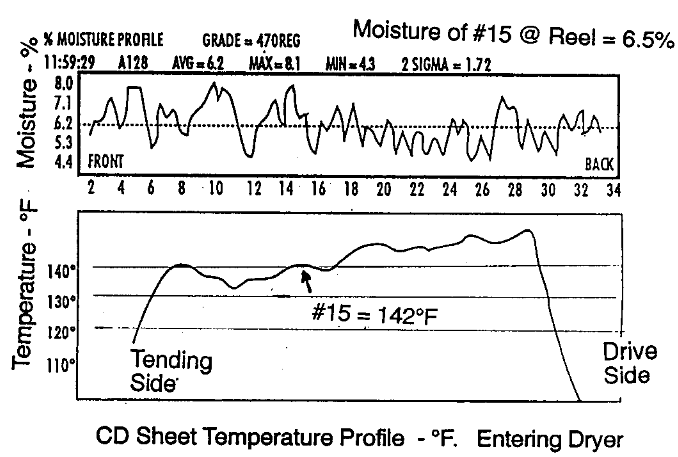

Fig. 16 - Immediately after the #15 actuator was put back in service the wet streak and cold streak disappeared.

This particular profiling steam shower included pointers on the actuators which are visible from the catwalk at the tending side of the machine. The operators were able to confirm that the air signal from the control panel truly wasn't reaching the actuator without having to take the steam shower off the machine. If the operators hadn't been able to see the pointers, the abrupt blip in the CD temperature profiles downstream of the steam shower would have quickly led them to the problem.

Conclusions

A hot sheet drains better than a cold sheet. Sheet cooling sources such as a suction couch can quickly be identified with an infrared temperature gun. Temperature surveys at the wet end can also help identify where water is being removed from the web. A poorly designed or operated steam shower can cause non-uniform temperatures and moistures in both the cross machine and machine directions downstream. The effectiveness of all types of steam showers can be measured by documenting sheet temperatures downstream. A properly designed and operated profiling steam shower is an excellent tool to preferentially heat the sheet, enhance water removal at the wet end and control moisture at the dry end. Sheet temperatures should be aggressively monitored on all paper machines.