

QUALITY IMPROVEMENTS TO PUBLICATION AND BOARD GRADES BY HOT CALENDERING WITH INDUCTION HEATING

Steven M. Zakaib, Business Manager Advanced Finishing Technology

E. Michael Heaven, P.Eng, Marketing Director

Robert Vyse, Research & Development Director

Measurex Devron

500 Brooksbank Ave.

North Vancouver, B.C.

Canada V7J 3S4

Abstract

The application of single and tandem induction heating systems on conventional calenders on mechanical pulp publication grades and high-quality board grades optimizes the calendering process on conventional calenders with increased roll temperatures. Hot calendering provides many improvements in sheet printability, strength, bulk, elimination of two-sidedness and optimized calender configuration. The papermaker can also benefit from an increased moisture average, flat caliper profiles, and improved calender, winder and pressroom runability.

A system known as Advanced Finishing Technology (AFT) encompasses the CD control system actuators and algorithms for hot calendering. AFT also includes advanced control techniques to take full advantage of the unique opportunity presented by the use of these new calendering tools by coordinating their actions.

This paper will focus on the application of single induction heating systems on linerboard and folding boxboard machines, and of tandem induction heating systems on newsprint and groundwood paper machines, as well as the benefits obtained to date.

Introduction

Much work has been done in the area of hot calendering over the last three decades. The many experiments have demonstrated the benefits of calendering at elevated roll surface temperatures and increased web surface moistures. The main problem has been the practical means of delivering the energy to the surface of the roll when the only existing media were hot water and steam flowing through the center bore of a solid roll.

Limited success was achieved on some newsprint machines with the use of heated thin-shelled rolls which were installed on some newsprint calenders. The paper quality benefits achieved did not justify either the high capital and maintenance costs, or the resulting caliper profile problems. The temperature differentials across the face of the roll shell became an issue, as well as the temperature differentials through the thickness of the shell on high-speed paper machines. On board machines, high sheet temperatures in the range of 75-125°C (167-257°F) entering the calender stack do not lend themselves to significant additional heating with water or steam, creating a third limitation

More recently, a new opportunity has been presented to papermakers to rejuvenate their existing calendering operations by adding induction heating for

mass surface heating of the hard calender rolls, a technique developed as part of the Advanced Finishing Technology (AFT). The advantage of induction heating is that the energy is applied directly to the surface of the steel roll and induction energy is always additive to the existing roll surface temperature. This has become an opportunity for papermakers to achieve significant paper quality benefits without incurring the substantial capital expense of replacing all or part of the calender.

For groundwood grades such as newsprint, these techniques were described by Fitcher, Nykanen and Sipi [1]. Their studies made extensive use of external induction heating and dry-end steam showers to compare soft-nip calendering, thermal-gradient calendering, and 4-roll hard-nip conventional calendering. The closing statement in the paper states, "The normal 4-roll hard-nip machine calender was shown to be capable of producing competitive sheet qualities when compared with soft calendering and TG calendering, showing that this calender concept is still viable and by no means out of date." The effects of temperature, load and calender condition on finished paper qualities have been documented in various papers [2],[3],[4].

Over the past ten years, extensive research and development in the application of induction heating

systems on publication and board grade machines have been carried out. This work has resulted in the application of single (Figure 1) and tandem induction heating systems (Figure 2) to conventional hard-nip calenders. The objectives were to take roll surface temperatures well beyond the normal operating range and achieve significant improvements in sheet properties.

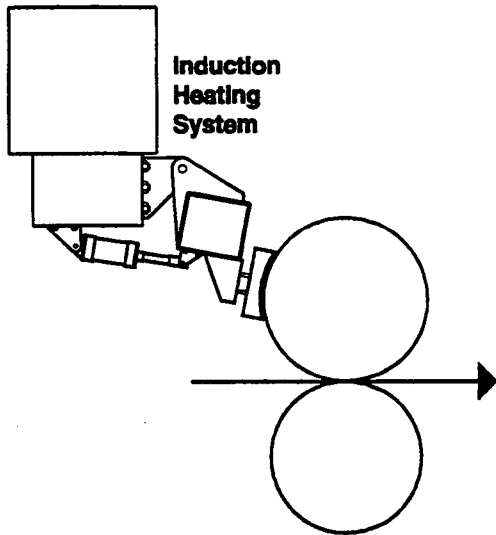


Figure 1: Typical single induction heating system application on a board machine with single nip calender

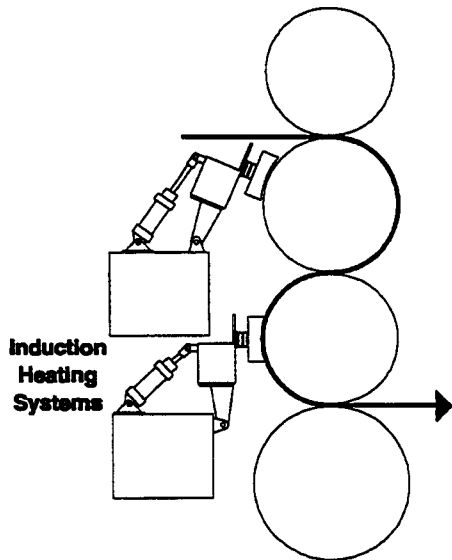


Figure 2: Typical tandem induction heating system installation on newsprint machine

Internal Roll Heating

Internal roll heating has been practiced with varying degrees of success for many years. There are several basic disadvantages to this approach:

- Very high internal fluid temperatures are required to overcome the difference in temperature across the shell wall which results from the heat flow to the web (see Figure 5a). In high temperature applications, this can overstress the shell wall and cause mechanical failure of the roll.
- The CD temperature profile of the roll surface cannot be corrected. CD temperature variations may result from inherent roll design characteristics or from the paper web non-uniformities such as CD moisture streaks.
- The excessive thermal inertia of internal heating systems delays the roll surface from reaching operating temperatures at startups, after sheet breaks and at grade changes. In high temperature applications, these rolls have specific temperature ramp-up rates of 1° or 2°C (2° to 4°F) per minute to prevent mechanical failure of the roll caused by the difference in temperature across the shell wall.

External Induction Heating

External induction heating, using 75 mm (3 inch) individually-controlled zones, addresses these limitations in a very practical manner:

- Allowing roll surface temperatures of up to 250°C (482°F)
- Compensating for CD variations in roll surface temperature
- Balancing out the heat flow across the internally heated shell, reducing shell stress and heat-up times
- Replacing all or a portion of the heat lost to the sheet
- Rapidly applying energy at startup
- Rapidly removing heat at sheet breaks

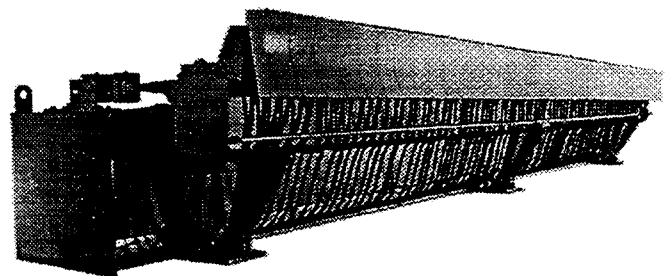


Figure 3: Typical induction heating system

A typical segmented zone external induction heating system is shown in Figure 3. This system applies a high frequency AC power to a coil winding, which creates an induced field in the roll shell, as shown in Figure 4. The field penetrates the surface and generates resistive heating on the roll surface. The system features instantaneous power on and off, precise power regulation, heat transfer independent of roll temperature and high efficiency, typically 90%.

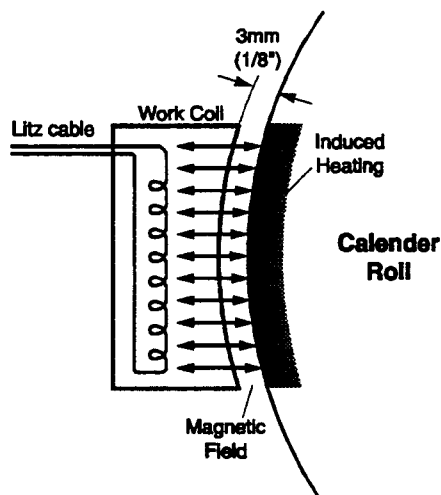
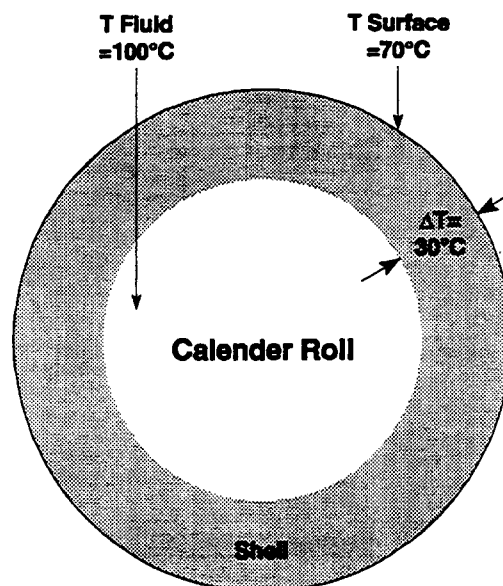


Figure 4: Principle of operation for induction heating systems

Figure 5a shows the temperature profile through the roll shell that might exist when all the surface roll heating comes from the internal roll fluids. Typically, a difference in temperature of at least 30°C (86°F) is seen across the roll shell thickness: for example, a surface temperature of 70°C (158°F) would exist for a 100°C (212°F) internal fluid temperature. Figure 5b shows that the difference in temperature can be reduced, eliminated or improved if the surface temperature is augmented by a base load, typically 30% to 80% of the energy available with the external induction heating system.

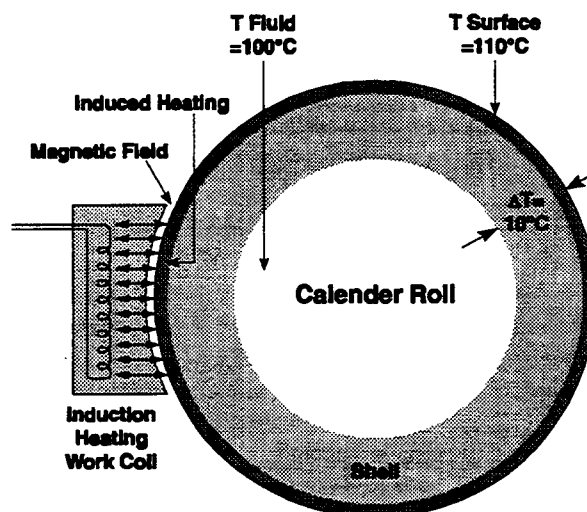
As shown in Figure 6a, the method used is to base load the average power output of the induction heating system to 50%, and use the balance of available energy to profile for CD caliper, smoothness and/or gloss. This can be accomplished with the specially developed AFT algorithms. Figure 6b demonstrates the instantaneous response of induction heating to a sheet break. First, the average power output is lowered to keep the roll surface temperature at normal operating levels while maintaining the desired profile shape. When the sheet is rethreaded, the average output power quickly returns to the desired setpoint and sheet

properties are kept within specification. The same techniques are employed during grade changes and at machine startup to maintain the roll surface temperature at the optimum level to ensure quality production.



A - Internally Heating Only

Figure 5a: Temperature profile through roll shell



B - Internal Heating Plus External Induction Heating

Figure 5b: Typical segmented zone external induction heating system

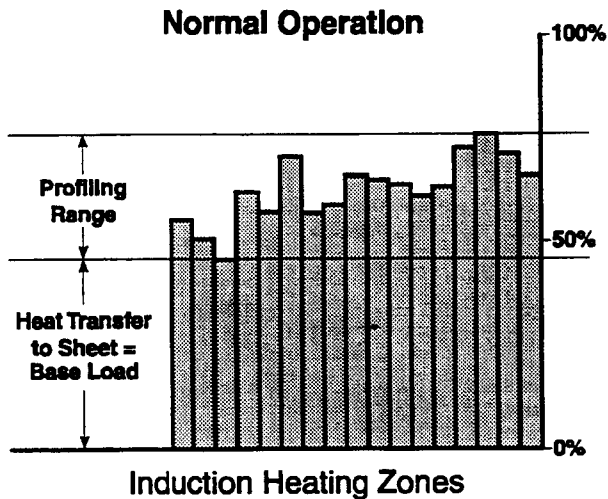


Figure 6a: Increased roll surface temperature through base loading

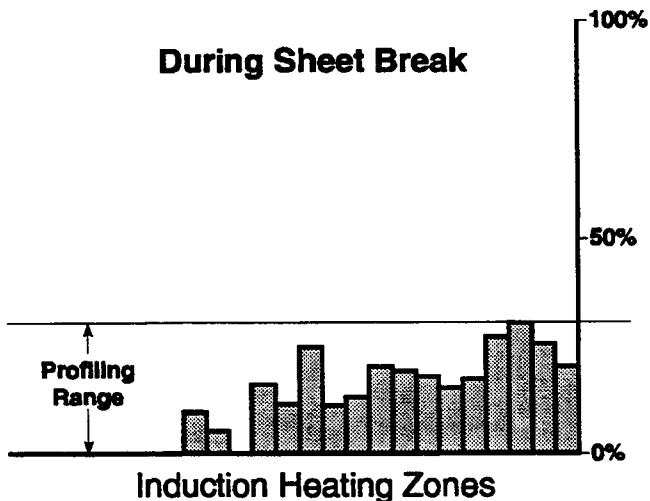


Figure 6b: Response at sheet break with induction heating

The principles of AFT exploit the basic laws of calendering as shown in Figure 7. External induction heating introduces a new and powerful tool to the papermaker to control the surface temperature of the hard rolls of the calender, and independently affect the top and bottom printability of the sheet and the mechanical properties of the paper web.

Single Induction Heating System Applications on High Quality Board Grades

Most high quality board machines have single nip calenders at the reel and before on-machine coaters. The amount of energy that induction heating can add

to the calender roll surface is most affected by machine speed. Figure 8 demonstrates some basic curves for the relationship between machine speed, average power output and roll surface temperature increase which can be expected on a single nip conventional hard-nip calender. As speed increases, the temperature rise lessens as the calender roll transfers more heat energy to the board. At the slower speeds of most board machines, the residence time of the roll in front of the induction heating system increases and thus the surface temperature rise is greater.

Case A – Linerboard

A European white top linerboard producer applied a single induction heating system to the top roll of the single nip calender with these characteristics:

- Basis weight range: 125 to 300 g/m² (77 to 189 lb/3000 ft²)
- Machine speed: 740 m/min (2428 ft/min)
- Sheet trim: 6150 mm (242 inches)

The original goals for this installation were to provide superior CD caliper profiling capability and to improve roll structure. Once this was achieved, using 20% to 40 % of the available output power, the mill decided to base load the induction heating system to increase the roll surface temperature and improve surface smoothness.

As shown in Figure 9, the installation yielded the following results:

- Smoothness was improved by 24% from 230 Bendtsen to 178 Bendtsen
- CD caliper 2-sigma was reduced to and maintained at 0.1 micron (0.004 mils) even at 60% average power output.

Case B – Board

At a European coated folding boxboard mill, a single induction heating system was installed on the top roll of a single nip pre-coater calender. The induction heating system was intended for both CD caliper profiling and for improved surface smoothness from increased top roll surface temperatures. The operating conditions were:

- Basis weight range: 300 to 600 g/m² (203 to 405 lb/3300ft²)
- Machine speed: 250 to 300 m/min (820 to 984 ft/min)
- Sheet trim: 6172 mm (243 inches)

The Interrelationships of Calendering Variables on Sheet Properties

Increasing Calender Parameter Paper Properties		Number of Nips	Nip Load	Machine Speed	Sheet Temperature	Web Moisture
Caliper		↘	↘	↗	↘	↘
Smoothness		↗	↗	↘	↗	↗
Tensile	MD	↘	↘		↗	
	CD	↘	↘		↗	
Tear	MD	↘	↘		↗	
	CD	↘	↘		↗	
Stretch	MD	↘	↘		↗	
	CD	↗	↗		↗	
Burst		↘	↘		↗	

Figure 7: Basic laws of calendering

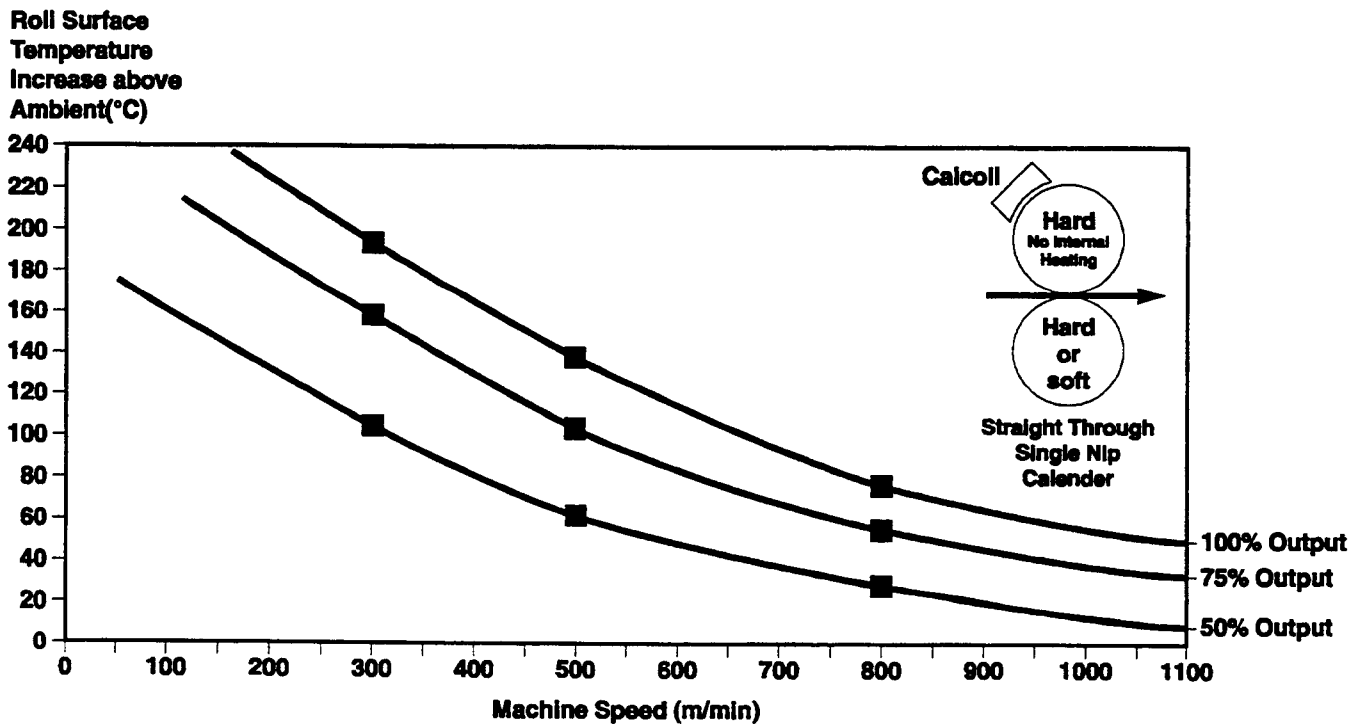


Figure 8: Relationship between machine speed, average power output and roll surface temperature increase

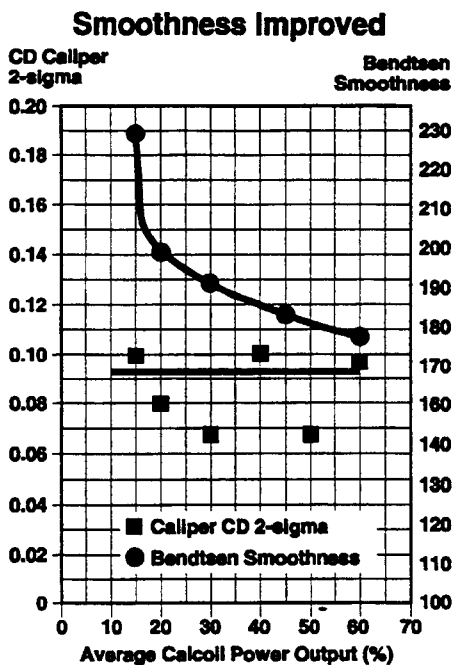


Figure 9: Case A – Results

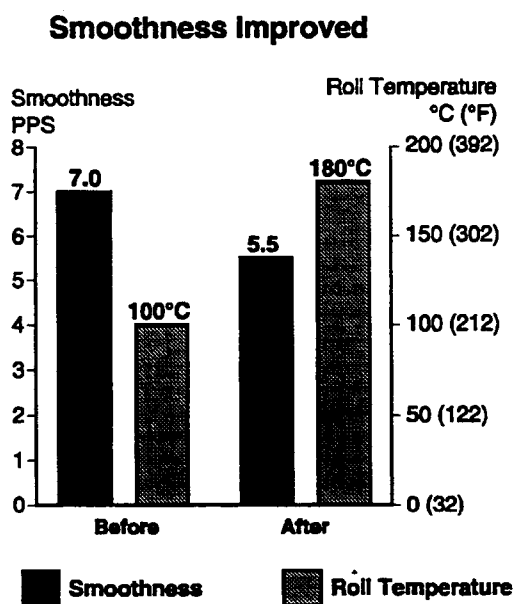


Figure 10: Case B – Results

As shown in Figure 10, the installation yielded the following results:

- Sheet smoothness was improved by 21% from 7.0 PPS to 5.5 PPS
- Roll surface temperature increased by 80°C (176°F)
- CD caliper 2-sigma was maintained at or below 1% of process

Tandem Induction Heating System Application on Publication Grades

The application of tandem induction heating systems on conventional calenders, as shown in Figure 2, on publication grades such as newsprint, directory and groundwood specialties has grown over the last three years. Figure 11 lists the sites in North and South America and the primary objectives of each project. It is interesting to note the flexibility of the tandem induction heating system as a calendering tool with the variety of calender applications. These range from older A-frame calenders with solid rolls in the intermediate positions and a swimming roll in the King position; to more modern L-frame calenders, some of which have calender tools such as nip relief, loading arms and multiple swimming rolls.

Case C – Publication

Mill C had an urgent requirement to dramatically improve sheet strength. Soft-nip calendering, thermal gradient calendering and new high temperature hard rolls were investigated and compared to solve this problem. During the course of this investigation, the papermakers had the opportunity to visit several mills which were using single induction heating systems with base loading to reduce two-sidedness and mills which used induction heating systems along with steam showers to accomplish the same.

From the trial work carried out, and with data provided by various machine builders and consultants, they surmised that higher temperature calendering would yield significant improvements in sheet printability. They also knew they could solve the strength problem by eliminating two calender rolls from their seven-roll calender, but were concerned that smoothness would worsen and not meet specification.

To compensate, tandem induction heating systems were applied to the calender on the Queen and third rolls to control and maintain the top and bottom smoothness at the desired target, while allowing for the permanent removal of the sixth and seventh rolls in the calender stack. This installation yielded the following results:

- As shown in Figure 12, an increase in roll surface temperature from 50°C (122°F) to 80°C (176°F) yielded a 10% increase in sheet strength for the same smoothness
- As shown in Figure 13, the smoothness was maintained at existing levels of 3.35 PPS with 5 rolls at 90°C (194°F), as compared to 7 rolls at 55°C (131°F)

- Average sheet moisture increased by 0.5% to 1.0%
- Caliper 2-sigma was 0.15 to 0.20 microns (0.006 mils to 0.008 mils)

Case D – Publication

At mill D, it was desired to increase machine speed by 10% as part of an overall productivity improvement program. At the current speed of 545 m/min (1788 ft/min), it was difficult to maintain the required smoothness levels for the high quality groundwood grades produced.

With a double A-frame calender configuration of 8 rolls in the first calender stack and 6 rolls in the second calender stack (Figure 14), the options for maintaining sheet finish and increasing machine speed without an expensive new calender installation were limited. The best option for this mill was to install tandem induction heating systems on the Queen and third rolls of the second calender stack, as shown in Figure 15. Not only was this a cost-effective solution but delivery time was 5 months as compared to 14 to 18 months for a new calender. This meant they could get on line faster and improve their bottom line within the same fiscal year.

Tandem Calcoil Installations on Multiroll Hard Nip Calenders

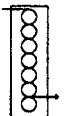
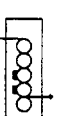
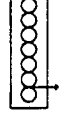
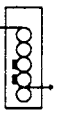
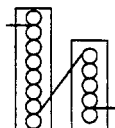
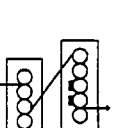
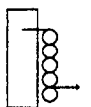
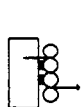
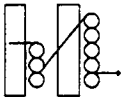
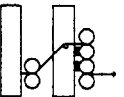
Case	Trim	Speed	Grade	Existing Calender	Reconfigured Calender	Goals	Startup
A	6000 mm	1000 mpm	Newsprint			Reduce calender nips, improve strength, smoothness and eliminate calender bubbles.	1993
B	6000 mm	1000 mpm	Newsprint			Reduce calender nips, improve strength, smoothness and eliminate calender bubbles.	1993
C	8400 mm	1260 mpm	Newsprint			Improve smoothness and gloss.	1993
D	4000 mm	700 mpm	Roto			10% speed increase, reduce calender nips, maintain smoothness at current levels.	June 1996
E	6000 mm	1100 mpm	Flexo			Improve smoothness by 20%, eliminate two-sidedness, reduce smoothness culls and reduce caliper culls, reduce calender nips.	July 1996
F	6000 mm	1100 mpm	GWS			Improve smoothness to level normally achieved by 6 rolls, eliminate two-sidedness.	Dec 1996
G	8400 mm	1150 mpm	Newsprint			Improve smoothness, increase strength, reduce caliper and kraft usage, reduce calender nips.	Dec 1996
H	3800 mm	600 mpm	Directory			Improve smoothness, reduce kraft, reduce caliper.	June 1997

Figure 11: North and South American project sites and primary objectives

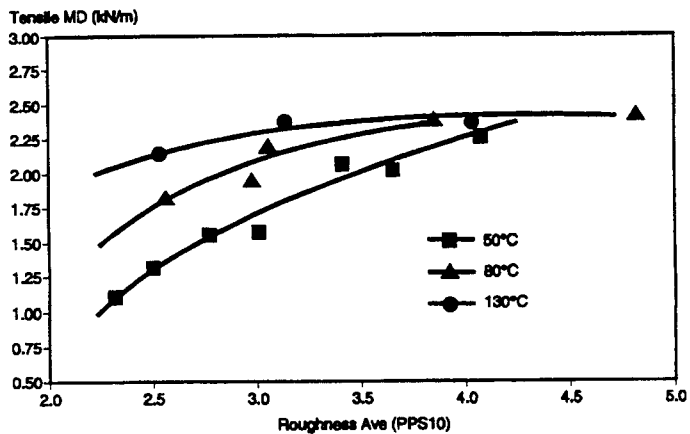


Figure 12: Case C – Increase in sheet strength resulting from an increase in roll surface temperature

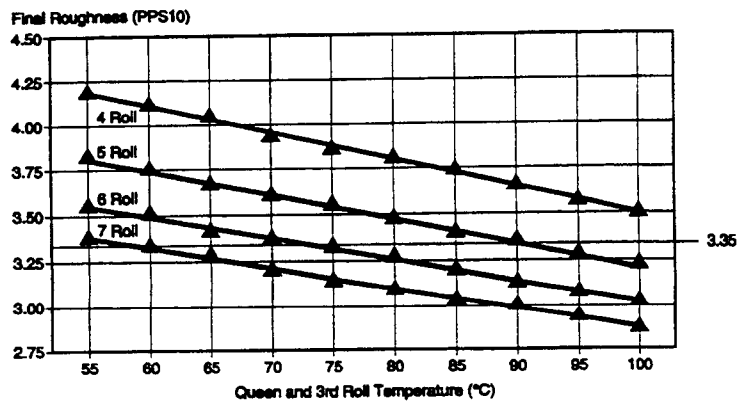


Figure 13: Case C – Smoothness maintained at existing levels with increased roll surface temperature, even with removal of two rolls

Calender Setup (before Calcoil)

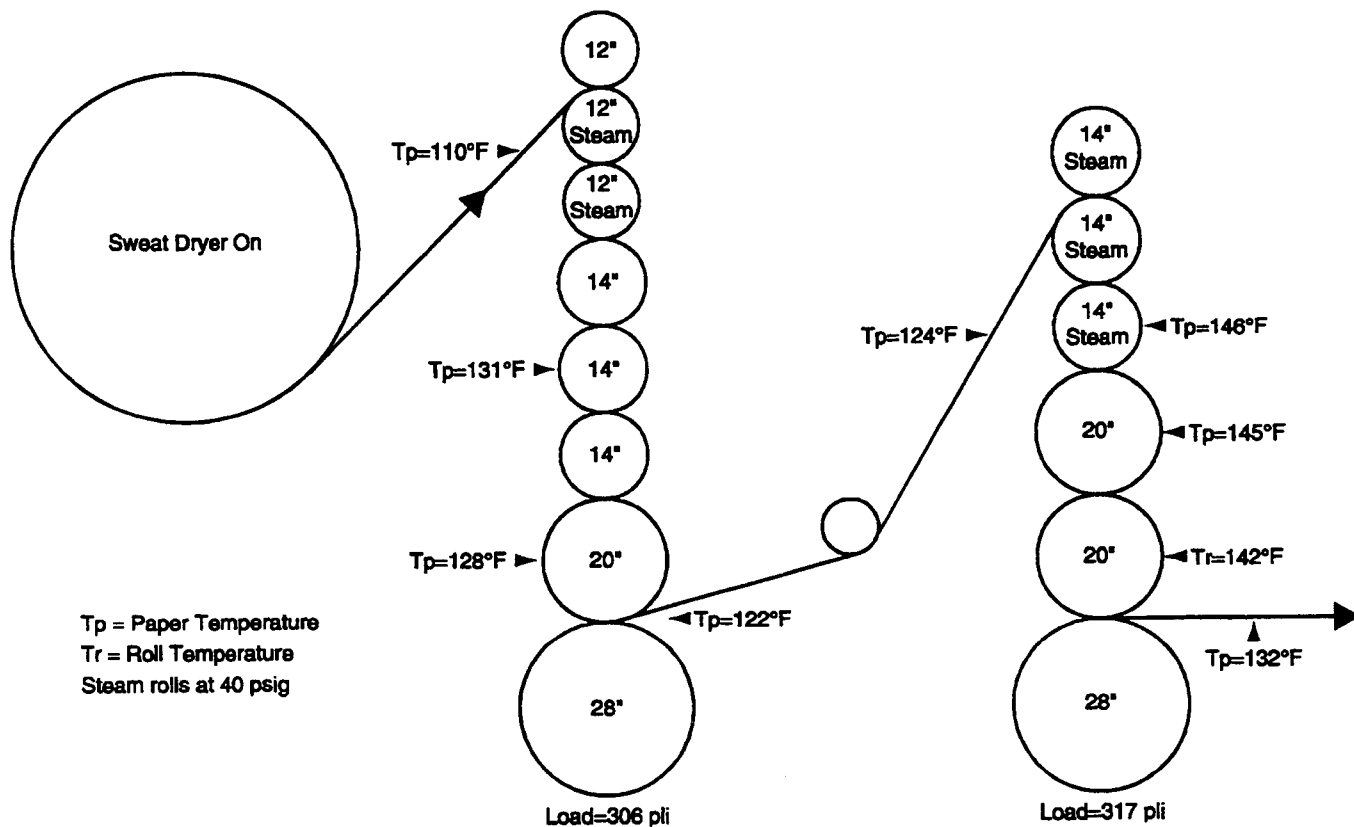


Figure 14: Case D – Double A-frame calender configuration before the induction heating system installation

Calender Setup (After Calcoil)

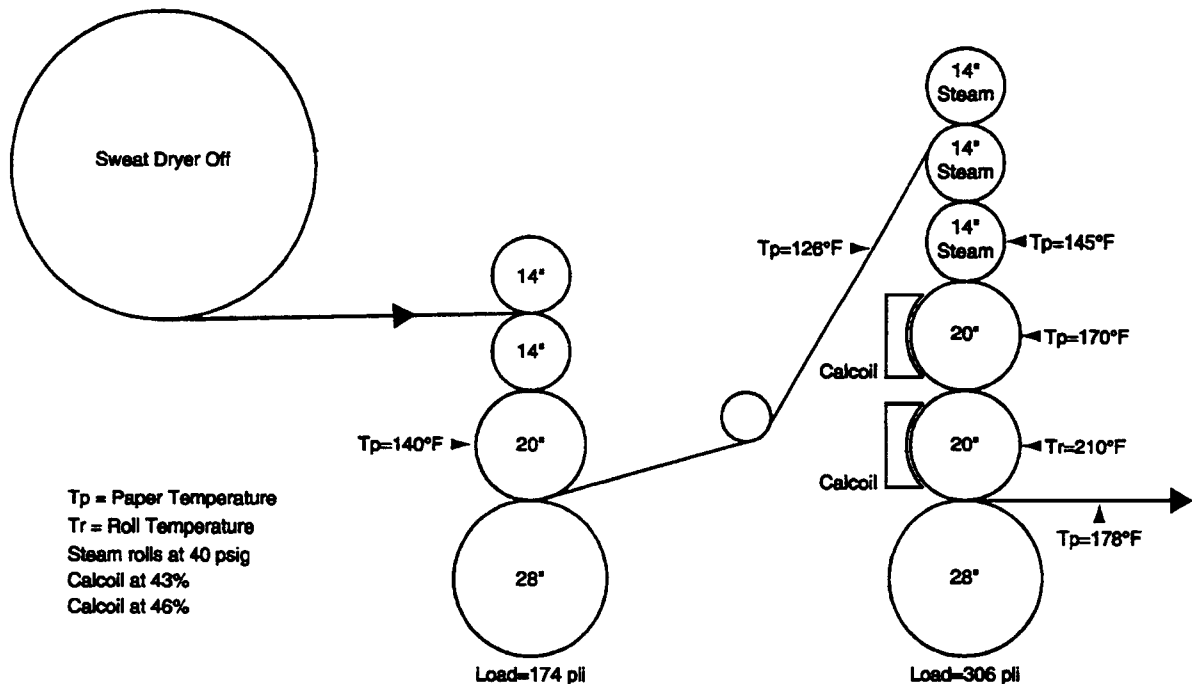


Figure 15: Case D – Calender setup with tandem induction heating systems installed on the second calender stack

Figure 16 shows the effects on caliper and smoothness after lifting four calender rolls in the first calender stack. The installation yielded the following results:

- Machine speed was increased from 545 m/min (1788 ft/min) to 596 m/min (1955 ft/min), while maintaining sheet printability and mechanical sheet strength properties
- Average caliper started at approximately 72 microns (2.8 mils) and settled at 74 microns (2.9 mils)
- Average CD caliper 2-sigma of 0.37 microns (0.015 mils)
- Average CD smoothness 2-sigma was reduced by 23% on the top of the sheet and by 17% on the bottom, yielding a more uniform sheet which was noted in the pressrooms
- With the removal of the four rolls in the the first calender stack, sheet threading has dramatically improved, causing machine efficiency to improve
- Maintenance savings resulted from the removal of the four rolls in the first calender stack

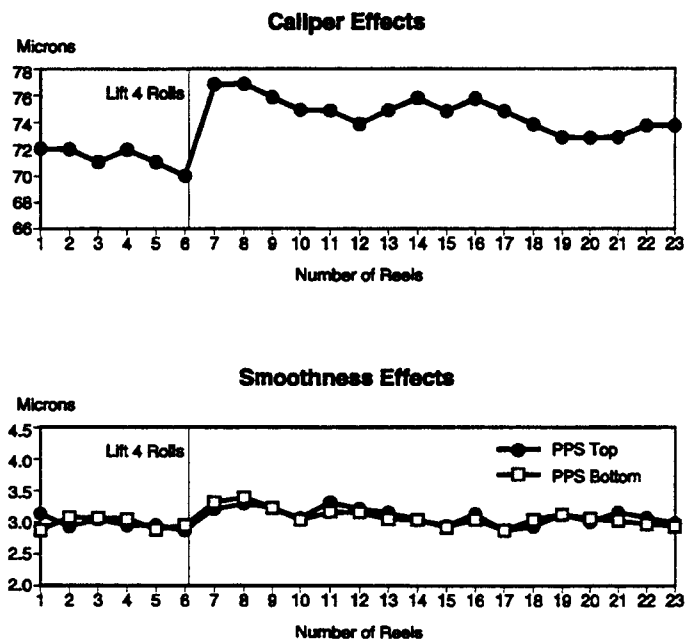


Figure 16: Case D – Effects on caliper and smoothness after lifting 4 rolls on first calender stack

Conclusion

Historically, induction heating systems were installed for superior CD caliper control on all calendered paper grades. Today, papermakers use this powerful tool to enhance web surface properties for improved printability and for greater flexibility in configuring existing calenders to meet the mechanical quality requirements demanded of the final product. The latter need may be to improve surface finish or to maintain existing surface properties while optimizing furnish mix. The requirement for a single or a tandem induction heating system is determined by the need for control on one or both sides of the paper web surface properties. A tandem induction heating system arrangement is recommended when the requirement is to:

- Improve sheet smoothness (printability) on both top and bottom of the sheet
- Reduce the number of calender rolls in the stack while maintaining smoothness at existing levels. This may be done to improve sheet strength, address problems such as calender bubbles or reduce the use of a high cost furnish such as Kraft pulp which is normally added for strength
- Maintain the physical properties of the paper web while improving smoothness and/or gloss to new levels for grade development
- Increase machine speed substantially while maintaining paper properties constant

Secondary benefits which can be expected from the installation of a single or tandem induction heating system are:

- Ability to increase average sheet moisture target
- Reduced corrugations by up to 40-50%
- Reduced hard/soft rejects by up to 80%
- Reduced smoothness rejects by up to 80%
- Reduced caliper rejects by up to 80%
- Reduced break recovery time by up to 60%
- Improved control of coat weight pickup

- Improved winder operations
- Improved pressroom runability

With multiple systems operational and more installations occurring in 1997, new results will soon be available to share with the industry in both mechanical pulp publication grades and high quality board applications.

The application of single and tandem induction heating systems on publication and board grade hard-nip calenders has produced significant results for the papermaker, making the operation more profitable while improving web quality. Over the next few years, we will be exploring the benefits of applying these same techniques to wood-free machines. The addition of new and powerful tools to the conventional hard-nip calender is producing significant paper quality benefits and optimized paper machine operation, and is ensuring the future of hard-nip calenders as an important piece of paper machinery.

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