Energy Efficiency of Steam Showers
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ABSTRACT

Steam showers heating the sheet during the forming and pressing process can remove more steam from the dryer than they are supplied with but the primary financial payback comes from improved sheet properties, machine runnability and dryer limited production increases. This paper documents dryer load reductions achieved by heating the sheet or press fabric on machines making pulp, linerboard and fine paper along with economic justifications of using steam showers. It discusses the most efficient locations to install a steam shower for various grades and machine configurations as well as recommended operating techniques. It also offers suggestions on how to optimize performance of a steam shower, evaluate benefits and justify the costs of installing and operating one.

INTRODUCTION

It is well accepted and obvious that less energy will be required in the dryer section of a paper machine if a drier sheet is sent to it. Increasing sheet solids from 47% to 48% entering the dryer reduces water load 4% as well as the amount of energy required to dry it. A machine whose dryer demands 80 klb/hr to increase solids from 48% to 95% would theoretically require only 74 klb/hr if sheet solids entering the dryer were 2 points higher at 50%. If the average cost of dryer steam is $6/klb and you save 6 klb/hr, potential savings is $36/hr or $864/day or about $300,000/year. With this in mind all efforts should be made to improve water removal from the web in the press section by optimizing press fabrics, reducing rewet, maintaining doctor blades and practicing good papermaking techniques to send as dry a sheet into the dryer section as possible.

It is easier to remove water at the wet end of the paper machine from a hot sheet of paper than a cold sheet. The most common method of heating the sheet is with a steam shower in the forming or press section of the machine. Widely reported and documented benefits from steam showers at the wet end include more uniform CD moisture profiles, reduced rewet leaving a press, stronger sheet properties, improved machine runnability, cleaner press fabrics and production increases of as much as 20% on dryer limited machines. An excellent review of publications discussing web heating and wet pressing was presented by Tim Patterson to TAPPI in 1999[1]. Discussion of steam showers and lists of published reports discussing steam showers effect on water removal and sheet properties can also be found in TAPPI TIP #0404-58 "Steam Shower Applications in the Forming Section"[2] as well as TAPPI's Wet Press Manual[3].

Less well publicized are case studies documenting the efficiency of steam showers on individual machines, specifically under what conditions does a steam shower remove as much or more steam from the dryer section as it is supplied with. Calculating the theoretical efficiency of a steam shower is easily done by running energy balances but documenting results from an operating steam shower is often complicated by many interrelated operating variables on the paper machine[4].

EFFICIENCY OF STEAM SHOWERS

Some important factors that contribute to efficiency of a steam shower in operation include the following.

1) Sheet properties such as porosity and weight of the web at the point of steam application (thermal transfer from a steam shower is generally most efficient with light, porous, mechanically refined furnish).
2) Degree of vacuum available to pull the steam into the sheet, (only as much steam should be delivered to the sheet as can be condensed in or on it).
3) Temperature and amount of water in the sheet at the application location (the cooler and drier the sheet the more efficient the energy transfer).

4) Speed of the machine hence length of time available to transfer energy from the steam to the sheet, (the faster the machine, the less temperature loss due to evaporative cooling from the surface of the hot sheet between the steam shower and the dryer section).
5) Number and efficiency of water removal devices downstream of the steam shower to pull or press water from the hotter sheet (for instance, heating the sheet or press fabric ahead of a shoe press is particularly effective due to softening of the fibers in the sheet).
6) The amount, temperature, and quality of steam that is supplied to the steam shower ("steam flow ratio" is pounds of steam supplied to the steam shower per pound of fiber produced) - generally, the lower the steam flow ratio the more efficient the steam shower. Especially for fast machines with limited, or no, vacuum assist below a steam shower, saturated steam condenses quicker than superheated steam. It is far better to supply a steam shower with low cost excess blow through or flash steam than vent it to atmosphere or into the wire pit where consistency is considerably lower than in the forming or pressing section.
7) Use of steam showers improves energy efficiency of the machine in ways other than increasing sheet solids or temperatures. Two of the most obvious benefits from steam showers include improved CD moisture uniformity so less there is less rejected paper and stronger sheet properties leading to a reduction in sheet breaks and improved overall machine efficiency. On machines making grades that require bulk such as milk carton stock, the drier and stronger sheet obtained by using a steam shower can allow for lower press loading and reduced mechanical refining thereby saving horsepower[5]

Perhaps most importantly the efficiency of a steam shower depends on the goals of the user and how it is operated. Mills with dryer limited machines that are able to sell everything produced often supply a steam shower with an excessive amount of steam to maximize production rather than save energy. Little attention might be given to excessive steam usage until the cost of steam supplying the steam shower exceeds the incremental profit from the additional production. Unfortunately, monitoring systems and their operators too often pay more attention to production related controls such as machine speed, sheet moisture at the reel and dryer steam pressure than to dryer steam flow or sheet solids leaving the last press. It can be difficult to document and compare a steam shower's effect on dryer steam flow if the control system is not set up to monitor it on a regular basis.

Weight of the paper grade determines where the steam shower should be located on a given machine. For most machines making heavy but porous grades such as pulp or most brown board the preferred location for a single steam shower is over the suction boxes on the fourdrinier downstream of the dry line. Although there's much more water in the sheet at this point to heat there is usually a suction couch and multiple nips downstream to remove the resulting hot water and applied condensate. Experience on pulp and porous linerboard machines suggests that as much steam will be removed from the dryer as is fed to a fourdrinier steam shower up to a steam flow ratio of about 0.10 lbs of steam per lb of fiber produced. Higher steam flows will increase dryer limited production but it is often more efficient to use that steam to feed a second or third steam shower strategically installed in the press section where the sheet is cooler and drier.

Optimum steam flow ratios to a steam shower anywhere on the machine are determined by how much steam can be condensed in the sheet. Steam bouncing off the sheet and entering the machine room as fog is wasted. Over refining of the furnish, certain top wire formers and poor vacuum setups in the forming section can tighten, or "seal" the sheet negating the benefit of vacuum assist. Efficiency of steam showers with or without vacuum assist can be improved by lengthening exposure time of the sheet to steam by positioning the steam shower in natural "tunnels" or "wedges" on the machine[6]. Examples of tunnels are bi-nip or tri-nip press nips while a wedge is often formed between top felts on linerboard machines equipped with a shoe press, ahead of the first press on a linerboard machine or last press on a newsprint machine (Figure 1).

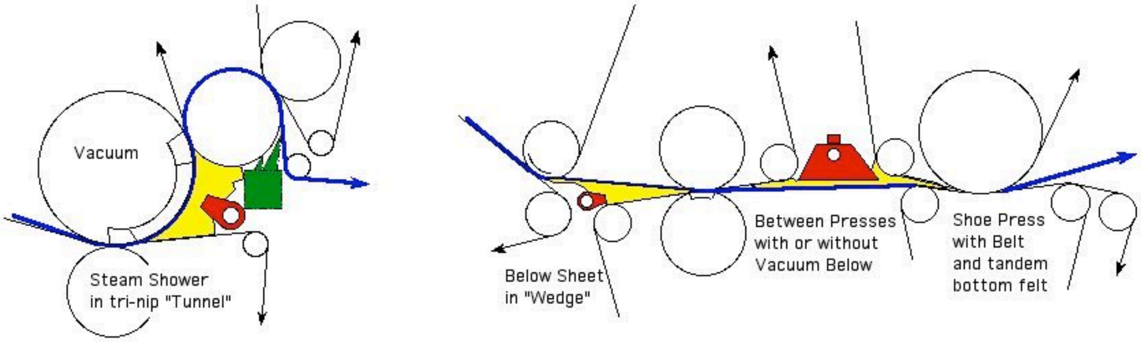


Figure 1. The efficiency of steam showers can be improved by containing and lengthening the exposure time of the sheet or fabric to steam application.

The lower the temperature of the web entering a steam shower, the better the efficiency of steam application. This is due to the steepness of the viscosity curve of water at low temperatures. Elevating the average temperature of water in a sheet of paper from 30°C (86°F) to 50°C (122°F) has about three times the effect on the water's viscosity as heating it from 70°C (158°F) to 90°C (194°F) (Figure 2). Because of this, there are diminishing returns from multiple steam showers on a machine. Surface tension is also reduced with increasing temperatures and is a very important factor in reducing rewet of the sheet leaving press nips as well as "sheet stealing" by a press fabric.

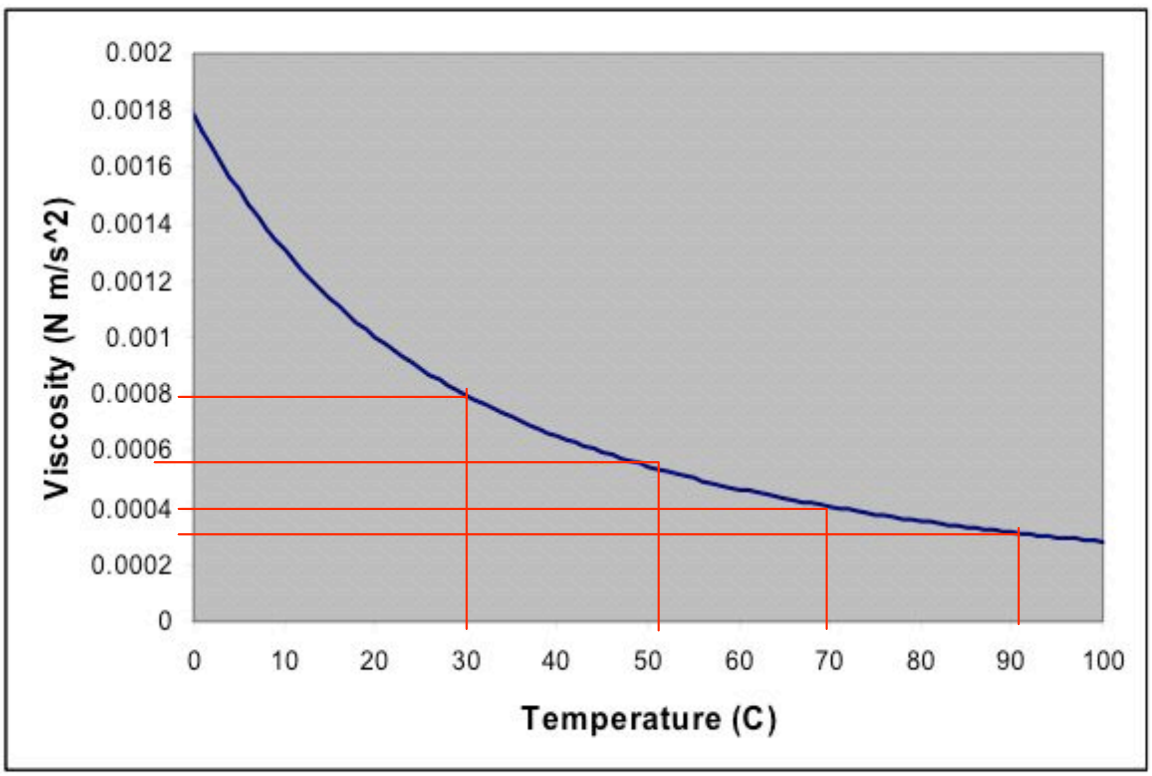


Figure 2 - Increasing the temperature of water from 30°C (86°F) to 50°C (122°F) has three times the effect on its viscosity than heating it from 70°C (158°F) to 90°C (194°F) The cooler the sheet the better the heat transfer from the steam shower.

To show the relative effect of steam application, Figure 3 illustrates top of sheet temperatures downstream of a single 6" wide compartment of a profiling steam shower box as the compartment was progressively opened from 0% to 100%. In this case, there is close to a direct relationship between delivery of steam and resulting surface temperature of the sheet downstream. Temperature of the bottom of the sheet is likely cooler than the top unless there is a great deal of vacuum below and the sheet is very porous.

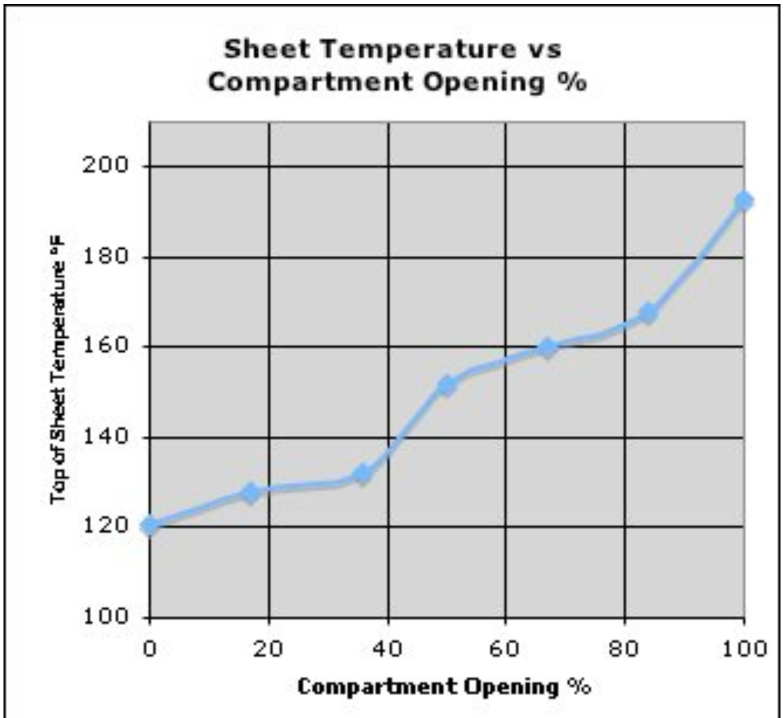


Figure 3 – Sheet temperature downstream of a steam shower increases proportionally to steam supply.

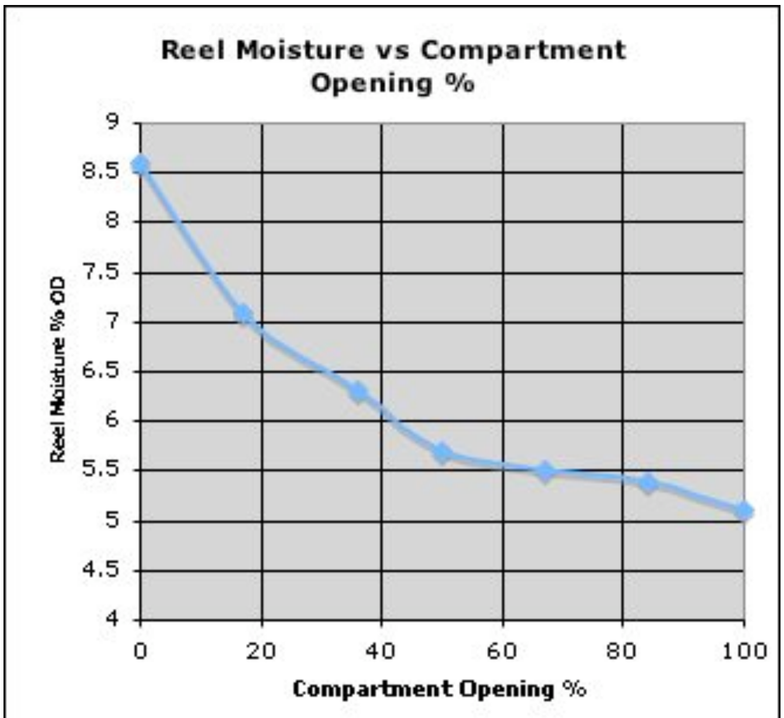


Figure 4 – Water removal in the press section and sheet moisture at the reel is most affected by the first amount of steam (heat) applied by a steam shower.

Figure 4 shows the effect on sheet moisture at the reel from heating the sheet on the fourdrinier. It is evident that opening the compartment from 0% to 50% increased sheet temperature from 120°F (49°C) to 150°(65°C) and was worth 3% at the reel. Additional heating to 196°F (91°C) had half the effect on water removal and reel moisture. Note the similarity between this curve and that of viscosity in Figure 2.

Reducing steam flow to this fourdrinier profiling steam shower would likely make the steam shower more energy efficient but in this case, there was a Flovac suction box under the steam shower. At lower steam flows contaminating air swept into the sheet around the edges of the steam shower resulting in non-uniform sheet temperatures and water removal downstream. For this application comparatively high steam flow was required for optimum moisture profile control.

If steam economy is a primary goal of a mill, consideration can be given to reducing vacuum in the suction boxes under a steam shower to allow for reduced steam flow to the steam shower. In any situation, a steam shower should be supplied with as much steam as the vacuum below will pull and condense in the sheet. If too little steam is supplied the vacuum below will pull in contaminating air from outside the steam shower. If too much steam is supplied excess steam will escape into the machine room where it condenses into worthless "fog", not on the sheet where desired. For new or replacement steam shower installations, consideration should be given to covering only the last two or three suction boxes on the fourdrinier instead of the last four or five flat boxes. Although average sheet temperature exiting the steam shower will likely be cooler, less steam will be required to satisfy the suction boxes. Steam supply to a non-profiling preheat section can be turned off to improve the energy efficiency of some designs of fourdrinier steam showers. Sending a cooler sheet under the profiling zone should improve condensation rates and make better use of CD moisture profile control. The saved steam from the preheat section can then be supplied to a second or third steam shower strategically positioned in the press section to increase sheet temperatures. Any profiling steam shower is more efficient than a non-profiling steam shower if steam is preferentially applied only where needed.

The graph below (Figure 5) shows the effect on automatically controlled machine speed caused by increasing steam flow to a profiling steam shower installed over the last four suction boxes on the fourdrinier of a machine producing 35 tph of specialty pulp.

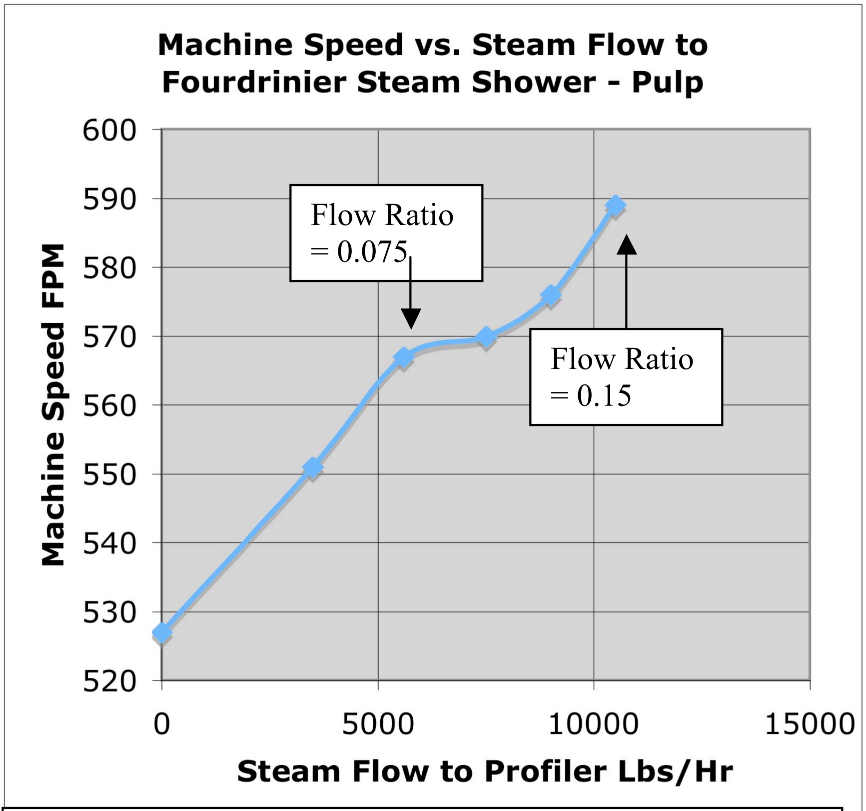


Figure 5 - The biggest effect on machine speed is obtained with comparatively low steam flow ratios.

Total steam flow of 10,500 lb/hr (4,773 kg/hr) netted a speed increase of 60 fpm (18 mpm) = 12%. It is apparent that the biggest gain, 40 fpm, (12 mpm = 8% = 8,400 lb/hr (3818 kg/hr) additional pulp), occurred up to a steam flow ratio of 0.075 = 5,500 lb/hr (2,500 kg/hr). Doubling the flow ratio to 0.15 lb/lb yielded another 20 fpm, (6 mpm =4% = 2,800 lb/hr extra pulp produced). Perfect 100% efficiency of the steam shower on this machine on this day would be obtained at a steam flow ratio of about 0.10 lb steam per lb of pulp produced.

Whether the extra 2,800 lbs (1,273 kg) of pulp produced each hour is worth an inefficient expenditure of 5,000 lb (2,273 kg) of steam per hour depends on performance of the profiler at low steam flow ratios, the dryer limitedness of the machine and whether the mill can sell all the pulp they make. Optimum steam supply to a steam shower is also influenced by other production criteria such as susceptibly to higher operating temperatures of a lumpbreaker cover and other press roll covers downstream, safety around the wet end, cleanliness issues such as condensation and dripping from cool overhead structures and the product being made. This particular machine was making specialty pulp for photographic paper that requires a lot of bulk. Since a hot sheet is more easily compressed in the press section than a cool sheet they might consider using less steam in their fourdrinier steam shower and installing a second steam shower ahead of the last press so there is less pressing of the hot sheet. Early presses normally provide higher bulk reduction than later presses where the sheet is drier.

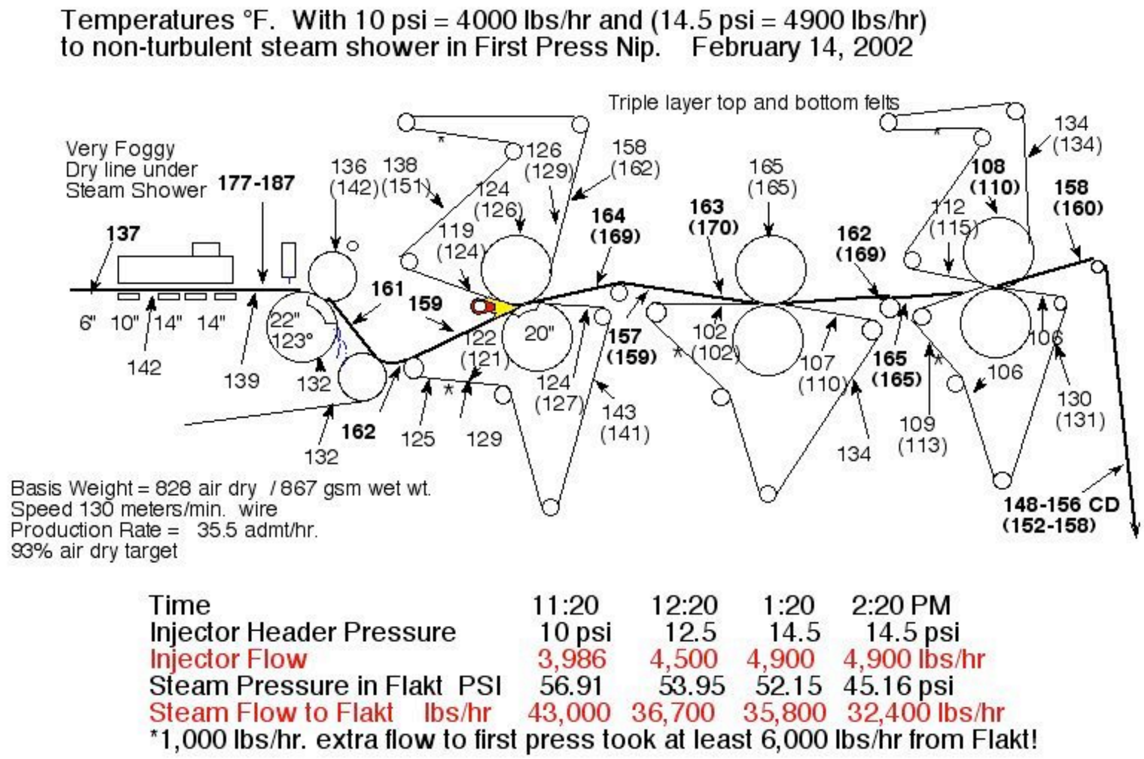
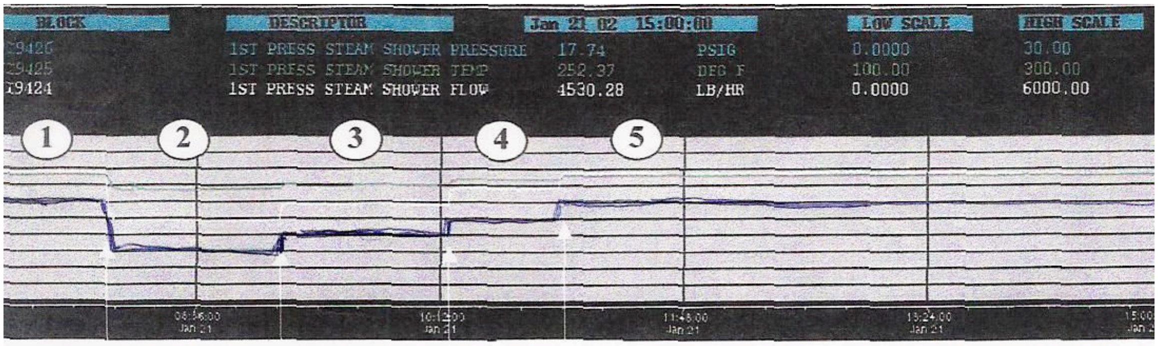


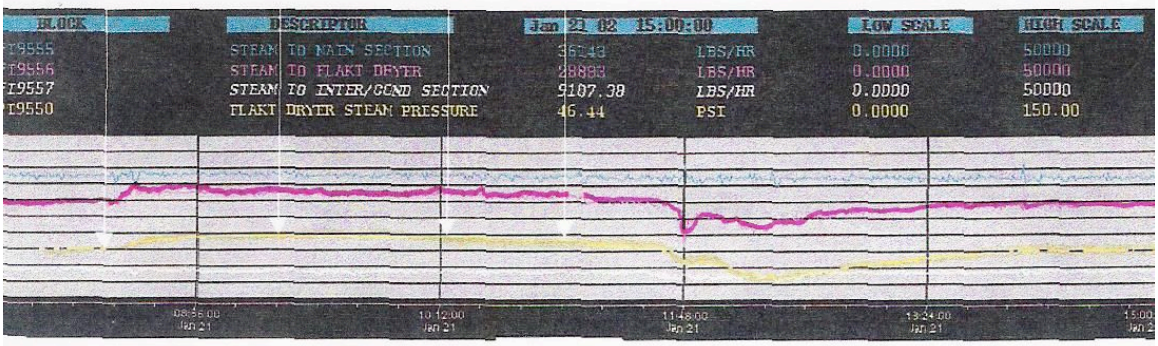
Figure 6 - Flakt steam demand and sheet temperatures downstream of a press steam shower supplied with flow ratios of 0.056 and 0.070 lbs steam/lb pulp.

Press section steam showers are typically more energy efficient than fourdrinier steam showers because there is significantly less water in the sheet to heat.

The temperature diagram of Figure 6 illustrates a Lazy Steam Injector mounted in a double-felted suction press nip of a market pulp machine in New Brunswick with a dryer section consisting of both a Flakt and cylinder can dryers. Replacing cooling air sweeping through the sheet in the press nip with 4,000 lb/hr (1,820 kg/hr) of pure, non-turbulent steam resulted in a 5°F (3°C) sheet surface temperature increase leaving the nip instead of a 5°F (3°C) drop without steam application. Note sheet temperature was already quite high at 160°F (71°C). The production rate on this machine was 35.5 admt/hr (852 tpd) so the steam flow ratio was a very economical 0.056 lb of steam/lb pulp produced. To better satisfy the vacuum of the press steam flow was increased by 1,000 lb/hr (454 kg/hr) (to a flow ratio of 0.70 and total of 4,900 lb/hr (2,227 kg/hr)) over a period of 2 hours causing steam demand by the Flakt dryer to drop more than 6,000 lb/hr (2,727 kg/hr)! It is clear from this hands on trial that additional steam flow to the first press steam shower was more than 100% efficient.

Illustrated below are printouts and data from an identical optimization trial conducted by the mill the week before (Figure 7). On this day, increasing first press steam shower flow by 1,740 lb/hr (from 2,910 lb/hr to 4,650 lb/hr) also reduced Flakt steam usage significantly (4,000 lb/hr (1,818 kg/hr)). Unfortunately, the mill was unwilling to turn the steam shower completely off to document the full effect of heating the sheet on Flakt steam demand but, based on experience as outlined in Figures 3, 4 and 5, the first amount of steam applied would have been more dramatic than simply adding more steam.





Operating conditions for drying response trial

trend	*Steam Injector*			*Flakt*	
	Flow (#/hr)	Temp (deg F)	Pressure (PSIG)	Flow (#/hr)	Pressure (PSIG)
color	White, top	Green, top	Blue, top	Pink, bottom	Yellow, bottom
1	4650	252	18.1	29500	44
2	2910	234	9.3	32500	57
3	3500	241	11.7	32500	57
4	4070	246	14.6	31200	53
5	4650	251	17.7	28500	44

Machine conditions during trial

Mach speed	130 mpm
Grade	Regular
Basis Wt.	91.0 large, 90.0 trim on BW valves
% Air dry	Dropped from 98.0% to 96.5% after step change
Steam to cans	38000 #/hr to Main section (~55 PSIG)

Figure 7 – Flakt dryer steam demand dropped with increasing steam flows to first press steam shower under controlled conditions by mill personnel.

The hands on trials and "gut feel" from the machine operators clearly indicate that this steam shower was more than 100% efficient since more steam was removed from the Flakt than supplied to the steam shower.

However, when calculating the efficiency of the steam shower on paper you get a different picture. On this machine making 35 tph, let's assume the sheet exits the dryer at 90% solids = 60,000 parts fiber and 6,660 parts water and enters the dryer with 50% solids (66,660 parts fiber and 66,660 parts water) so the dryer has to evaporate a total of 60,000 lb (27,273 kg) of water/hr. If the dryer requires 1.1 lb (0.5 kg) of steam to evaporate each pound of water, we should end up with a total dryer steam demand of 66,000 lb/hr (30,000 kg/hr). This figure corresponds to the combined steam demand from the main section of cans (38,000 lb/hr

= 1,727 kg/hr) and the Flakt (28,500 lb/hr = 12,954 kg/hr) with high steam supply to the steam shower illustrated in Figure 7.

This mill estimated that the non-turbulent steam shower in the first press provided a production increase of 3.7% = 1.23 tph = 30 tons/day beyond the initial rate of 800 tpd. This production increase figure may have been based on machine production over a period of a month, not just one hour.

Assuming 50% solids, the 1.23 tons of product @ 90% solids, contained 2236 lb (1016 kg) of water ahead of the dryer that had to be evaporated. If 1.1 lb of steam is required to evaporate each pound of water only 2460 lb/hr (1118 kg/hr) should be needed in the dryer section to produce that extra amount of product but the steam shower was consuming 4,000 lb/hr (1818 kg/hr). Using a dryer load figure of 1.1 lb steam per lb water evaporated suggests that the steam shower is only about 60% efficient. If the dryer required 1.2 lb of steam to evaporate 1 lb of water to produce the extra tonnage the steam shower would be only slightly more efficient at about 67%. In this instance, steam flow to the first press steam shower could have been reduced to a more efficient level but the mill's focus was in producing more pulp per hour. They did not mind using an extra 13,000 klb of steam each year (=$65,000 /yr @ $5/klb) to produce an extra 10,500 tons of pulp each year (= $2.1 million @ $200/incremental ton produced).

The bottom line on the above discussion is the steam shower appeared more efficient in use than the commonly used industry guidelines suggested it should be. Another example of an apparently inefficient but valuable steam shower follows.

The data of Figure 8 was collected by a summer intern on an almost identical market pulp machine in British Columbia in 1988. This machine has only cylinder can dryers that are less efficient than a Flakt so efficiency of a steam shower should be even better. Standard production on this machine before installing the first press steam shower was 1,000 admt/day or 41.66 admt/hr. Based on air-dry reductions and monthly production figures it was determined that the steam shower increased production about 3% to 1030 admt/day. As experienced elsewhere, the biggest gain was obtained up to a steam flow ratio of about 0.075 lb of steam per lb of pulp produced. Increasing steam flows beyond that ratio had less effect on air dry at the reel but was justified since the price for pulp was high at the time and the machine was dryer limited. If the steam shower yielded an extra 1.25 tons/hr (2500 lb/hr) of pulp for an outlay of 6,000 lb/hr and the can dryers require 1.2 lb of steam to dry each lb of pulp the efficiency of this installation would be only 50%. We did not document steam loads by the dryer section at the time but the feeling of everyone involved was the steam shower removed more steam from the dryer than it consumed despite what the calculations claimed.

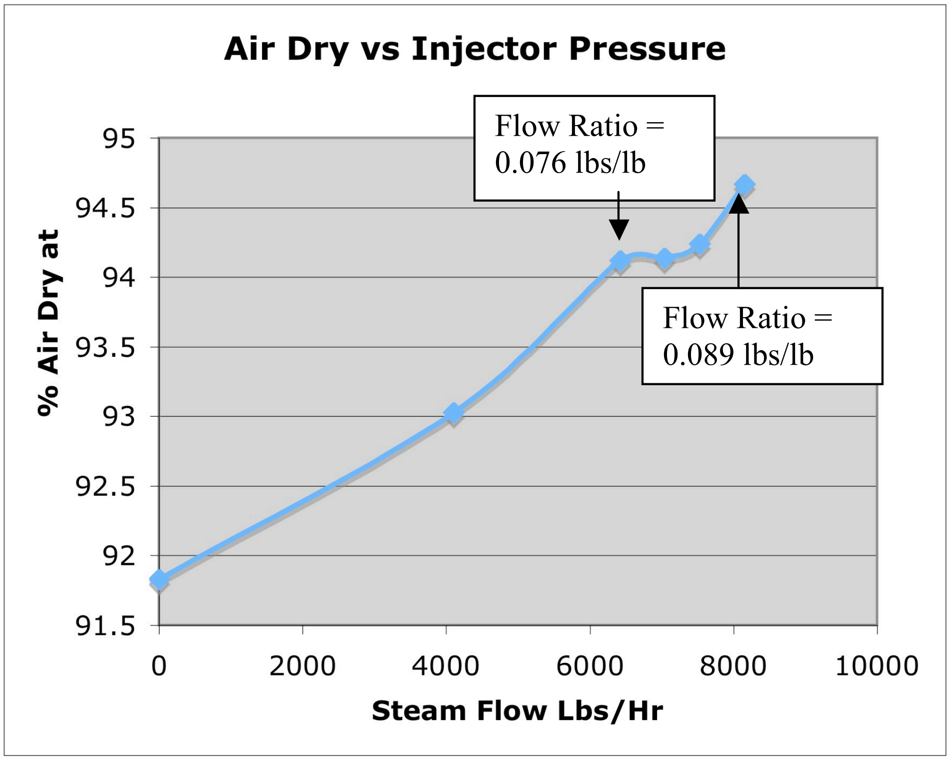


Figure 8 – Air-dry vs. steam flow to press steam shower on a market pulp machine with three straight through single felted presses.

This steam shower was used successfully for seven years until 1995 when it corroded due to presence of free chlorine in the hot, wet operating environment of the first press nip. At about the same time the mill top-felted the first and third presses so the machine was no longer dryer- limited. In the next few years subsequent upgrades were made to the pulp mill so the machine again became a bottleneck and in 1999 a replacement unit was installed in the same nip. Due to improved water removal by the top felts, (and perhaps lower, more efficient operating steam flow ratios), the mill documented that the new steam shower increased air dry at the layboy 1.3% vs. 3% with the old arrangement.

On this particular machine, a 1% increase in air dry is worth 1.5% production so the mill determined the steam shower increased dryer limited production about 2%. When summarizing the project, those responsible reported that increasing the air dry 1.3% saved $53,000 in shipping costs in one month and more than $500,000 for the year. Furthermore, they determined that the steam shower was worth at least 12 admt/day when production by the digester had to be cut back due to machine downtime and assumed the digester was curtailed 30 days/year so the additional production was 360 admt/yr or $126,000/year at an incremental cost per ton of $350. The mill boasted (to competitive pulp machines) that the project had a 6-week payback on an installed cost of $55,000.

The report neglected to mention that it cost nothing to run new steam piping since it was already in place from the original installation, nor did they include the cost of operating the steam shower in their summary. Under present 2006 conditions, assuming the steam shower was fed with 6,000 lb/hr (2727 kg/hr) of 65 lb steam priced at $5/klb 24 hours/day for 350 days/year the annual cost of steam consumption would be about $250,000, which reduces reported savings by 50%. The profitability of the installation was also compromised by shortened first press top felt life presumably due to overheating. As valuable as the steam shower was for increasing dryer limited production and reducing shipping costs, it was removed from the machine after less than one year of operation and put into storage. This steam shower will likely be installed for a third time when conditions and mill management change since it unquestionably increased dryer limited production and profits even if on paper it was not 100% efficient.

JUSTIFYING THE PURCHASE OF A NEW STEAM SHOWER

When calculating paybacks from new steam shower installations factors other than shipping cost savings to be considered include:

• The cost of steam piping, valves and a desuperheater is important when preparing an acquisition request for a new steam shower. Since the cost of installation is about the same or more than the price of the steam shower, the mill must assume some risk even if offered a 100% money back performance guarantee by the supplier. It is safer to solicit and compare proven performance records from similar machines when possible. Communication between mills of the same company via “best practices” internet sites is an especially valuable resource.

• Availability, cost and amount of steam to be supplied to the steam shower is important. Any mill venting low pressure flash steam to the atmosphere would be far better off applying it to a press fabric or the sheet even on an intermittent basis when the excess steam is available. The value of the condensate lost to the sheet should also be considered, particularly by mills with cogeneration plants on site.

• Limitations of the dryer section when making various grades are obviously important. If a machine manufactures 69 lb linerboard under dryer limited conditions and that grade represents 75% of the machine’s production, there is tremendous incentive to use a steam shower even if just used for that grade. An example of a less obvious payback from a steam shower happened to be a fine paper machine that was required to take over production of a heavy weight 100 lb cover grade from a sister machine just shut down. Water removal in their press section was so limited they couldn’t run the machine fast enough to make the grade until a steam shower was installed over the open couch. It is difficult to determine the payback under such conditions.

• Temperature limitations of existing equipment including press rolls, doctor blades and suction box covers should be considered before installing a new steam shower. Spares of susceptible equipment such as doctor blades should be on site.

• Maintenance and safety concerns should be addressed. Will a press section steam shower have to be moved for every felt or roll change and how much extra time will it take? Will excess fog from the steam shower limit visibility or access to catwalks or condense on overhead structures and drip. Pulp spatter from trim squirts that builds up and falls off a steam shower frequently results in removal from service even though it might have been more than 100% efficient when used.

• On the positive side, will use of a steam shower over a fabric uhle box eliminate the need to batch wash for twenty minutes per shift during which time access to the machine is restricted. Steam showers heating press fabrics are typically only 50% efficient but should allow for a reduction in high-pressure needle shower pressures, reduced vacuum in the uhle boxes and longer fabric life. A machine that changes three press fabrics at the same time every five weeks will go through a total of only 26 fabrics/year instead of 31 if a steam shower heating the most troublesome fabric yields an extra week of life and increases the rotation to six weeks. Improved runnability resulting from better sheet release leaving a press nip is a major benefit cited by mills heating and cleaning their press fabrics with steam showers. Reducing the number of breaks per shift by 50%, for instance from 10 to 5 can lead to an extra 30 – 60 minutes of production per shift, hence energy savings.

EVALUATING AND DOCUMENTING THE PERFORMANCE OF A STEAM SHOWER

The examples discussed so far discuss the effect of steam showers on comparatively slow stable pulp machines. Accurately documenting a steam showers effect on a faster fine paper or a brown-board machine that makes a wide variety of grades can be frustrated by either lack of monitoring equipment or lack of interest by the mill to quantify steam shower performance for different operating conditions. It is much easier to document results on machines with modern control and monitoring systems along with skilled engineers that know how to extract data from those systems.

Illustrated below in Figure 9 are temperatures collected soon after start-up of a steam shower in the first press nip of a fine paper machine in northern Maine. This machine was an ideal candidate for a steam shower since the sheet and fabric temperatures were only about 100°F (38°C) in the press section. The high vacuum zone of the press roll was obviously sucking cooling air through the sheet. There was a contained pocket, or “tunnel”, in that nip formed by the doctor blade and two press rolls, . The granite roll in this case, was able to withstand comparatively high operating temperatures and the suction roll is protected by the fabric. This machine is dryer limited, makes a high value LWC product and has only two presses. The last press fabric was not dewatered by a uhle box so we expected that most of the improved water removal from the hotter sheet would occur at the doctors and save alls on the press rolls. The application was especially attractive since the machine is equipped with a sophisticated DCS system with capability to document results and personnel well trained in its use.

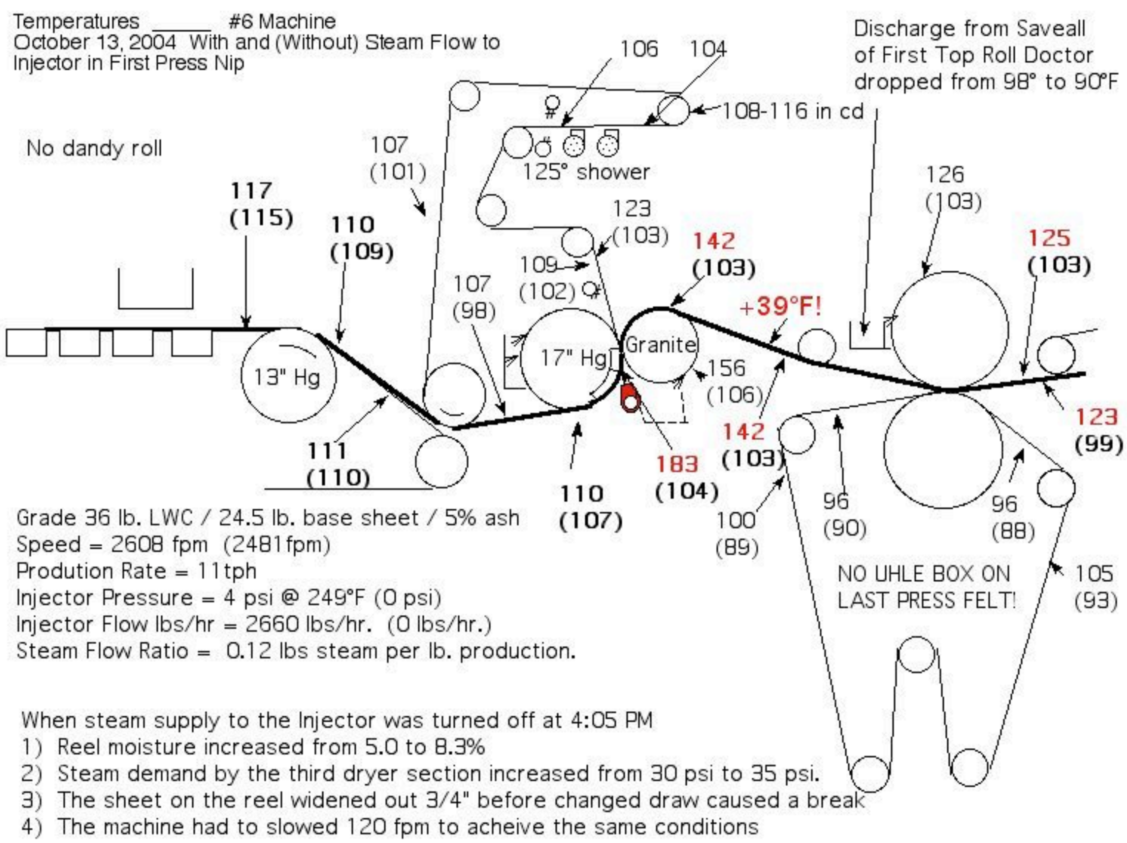


Figure 9- Temperatures with and (without) steam supply to first press steam shower on fine paper machine.

During a visit soon after installation and start-up the mill reluctantly agreed to turn off the steam shower for a short time so affect on sheet temperatures, moisture and steam load could be documented. As illustrated in the exhibits above and below, when steam was abruptly turned off at 4:05 PM sheet temperature plummeted 39°F (22°C) entering the second press and 20°F (11°C) entering the dryer.

A rule of thumb frequently reported is that each 18°F (10°C) increase in sheet temperature entering the last press is worth 1 point solids entering the dryer which should equal 5% production, 4% coming from a drier sheet and 1% from the hotter sheet. The 1% improvement due to increased sheet temperature is conservative if it allows a mill to use higher steam temperatures in the first dryer section without sheet picking.

Immediately after steam supply was turned off, sheet moisture at the reel increased from 5.0% to 8.3% causing the sheet to widen out ¾” on the reel. The draws immediately changed causing a sheet break. The machine had to be slowed down 127 fpm ((38 mpm) = 5% from 2608 to 2481 fpm (790 -752 mpm)) before third section steam pressure and sheet moisture stabilized at the previous levels of 30 psi (207 kPa) and 5.0% at which time steam supply to the shower was turned back on. Unfortunately, sheet samples entering the dryer were not collected nor was the control system set up to document the volume of steam flow to the third section at a pressure of 35 psi (241 kPa) without the steam shower vs. 30 psi (207 kPa) with the steam shower.

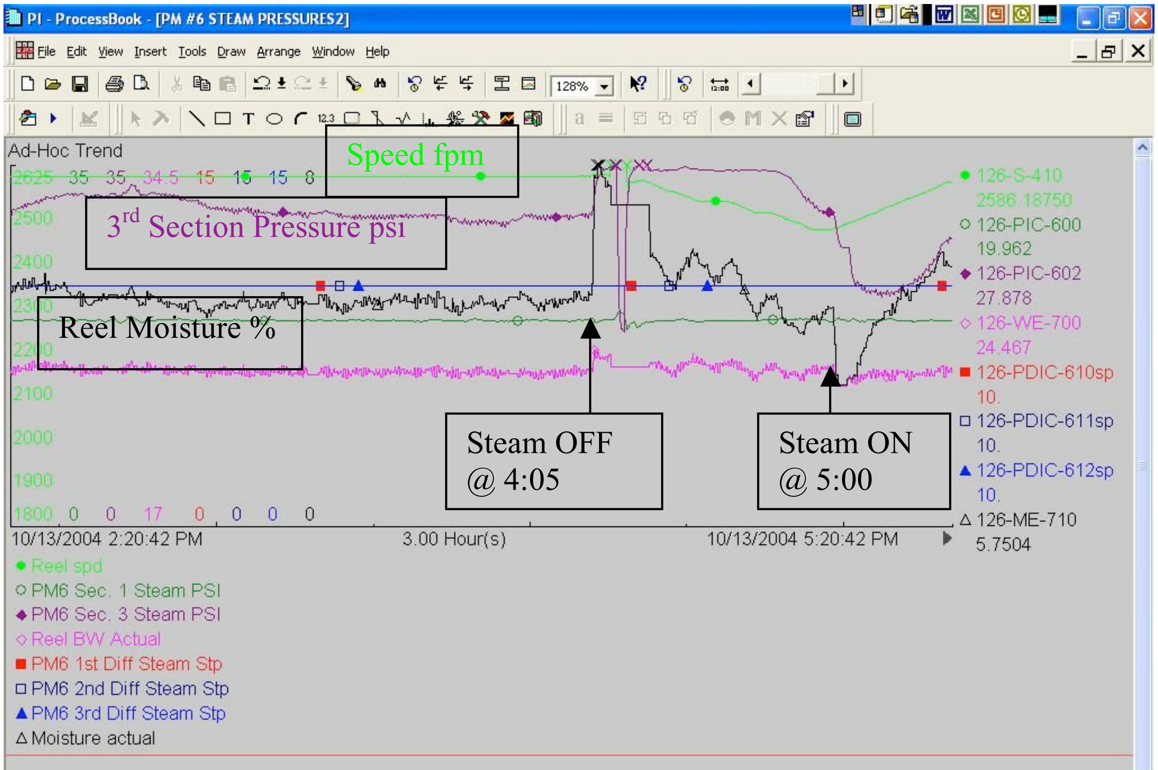


Figure 10- Sophisticated machine control systems ease documenting the value of a steam shower.

Steam application in this press nip reduced third section dryer steam pressure 16% and increased dryer limited production 5% and the mill claimed return on investment for the project was about 2 months.

On paper however, the steam shower is not a net steam saver since it used 2660 lb/hr (1209 kg/hr) of steam (a flow ratio of 0.12 lb steam/lb produced) at the wet end to produce an extra 1000 lb/hr (454 kg) of sellable product at the reel. The theoretical amount of steam required by the dryer to produce an extra 1,000 lb/hr (454 kg) of product would be 1980 lb/hr (900 kg/hr) assuming 43% solids entering the dryer, 8% solids at the reel, a production rate of 10 tph and a dryer usage of 1.2 lb of steam to evaporate each lb of water. To obtain 100% efficiency the steam shower would have to be supplied with only about 2,000 lb/hr (909 kg/hr= flow ratio = 0.10 lbs/lb) instead of the 2,660 lb/hr (1209 kg/hr = flow ratio = 0.13) yet yield the same speed increase. This steam shower is positioned about 3" from the sheet and press roll so as not to interfere with threading. If steam supply to the steam shower was reduced by 25% to make it 100% energy efficient, contaminating air could leak into the high vacuum zone of the press nip and cause non-uniform sheet temperatures, hence moistures downstream. It is conceivable that a carefully engineered steam shower with a sophisticated retraction mechanism could deliver steam more efficiently to the high vacuum zone of the nip but it would have to be mounted very close to the sheet and safely apply steam to the very crowded high vacuum zone of the press nip for it to be effective. Ironically, this mill had had bad experiences with just such steam shower designs.

In the example above, at least on paper, inefficient operation of the steam shower costs the paper mill an extra 660 lbs of 65 lb steam per hour x 24 hrs/day x $5/klb = about $80/day or $27,720/year. If the incremental cost per ton of production is $300/ton and the steam shower yields an extra 0.5 tons of paper each hour under dryer limited conditions it should pay for the extra steam consumption in about four days.

Not surprisingly, this mill, with six machines on site, quickly installed identical non-turbulent steam showers on two other machines in the complex with similar results.

One of those machines is located right across the aisle in the same machine room. The printout below shows steam demand by the automatically controlled second and third dryer sections over a period of eight hours for one hour of which steam was supplied to the newly installed steam shower. Note the short-term changes in moisture and dryer steam demand over time caused by unknown variables upstream.

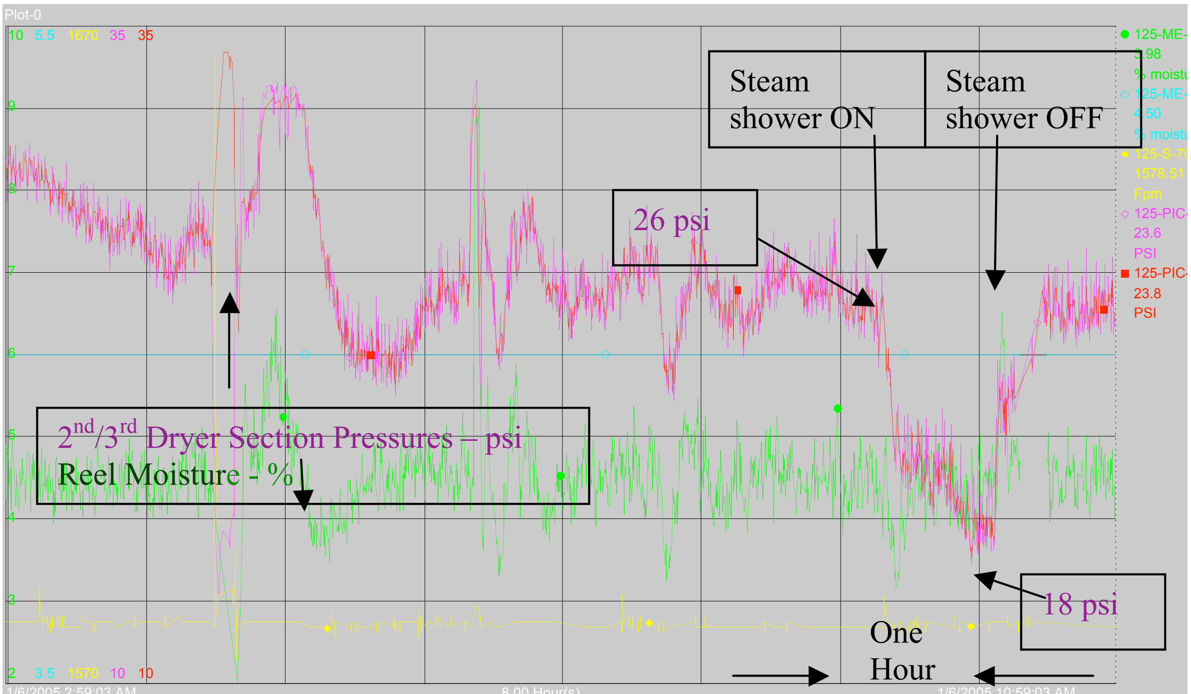


Figure 11 - Steam demand by the dryer dropped from 26 to 18 psi when steam was turned on to steam shower for one hour but there was much MD variability.

To better document the steam on-off trial, the time range and scales on the printout could have been adjusted to highlight and isolate the data of most interest. Short-term variability could be filtered to produce smoother curves but care must be taken when analyzing the results that dryer steam reductions are due to the steam shower and not due to changes in refining, stock supply, grade changes or other operating variables. Collection of trial data is much simplified if the machine operators refrain from making major changes while testing and are trained and encouraged to use the monitoring technology available to them. Having a quality printer available in the control room is also beneficial. Obviously, if the primary interest was to document the energy efficiency of the steam shower, it would be worthwhile to set up the monitors to measure dryer steam flows or total steam demand by the machine in addition to dryer steam pressures before trialing a steam shower.

Below is another example of data collected during an on-off trial of a steam shower heating the pickup fabric on a virgin kraft linerboard machine located in the southeast. The time span of the printout was reduced to just one hour with hopes to better define fifth section steam demand when the steamer was abruptly turned off then on again. The huge short term swings in sheet moisture at the reel make it difficult to claim that heating the press fabric on this machine was responsible for the 5-psi increase in fifth section pressure.

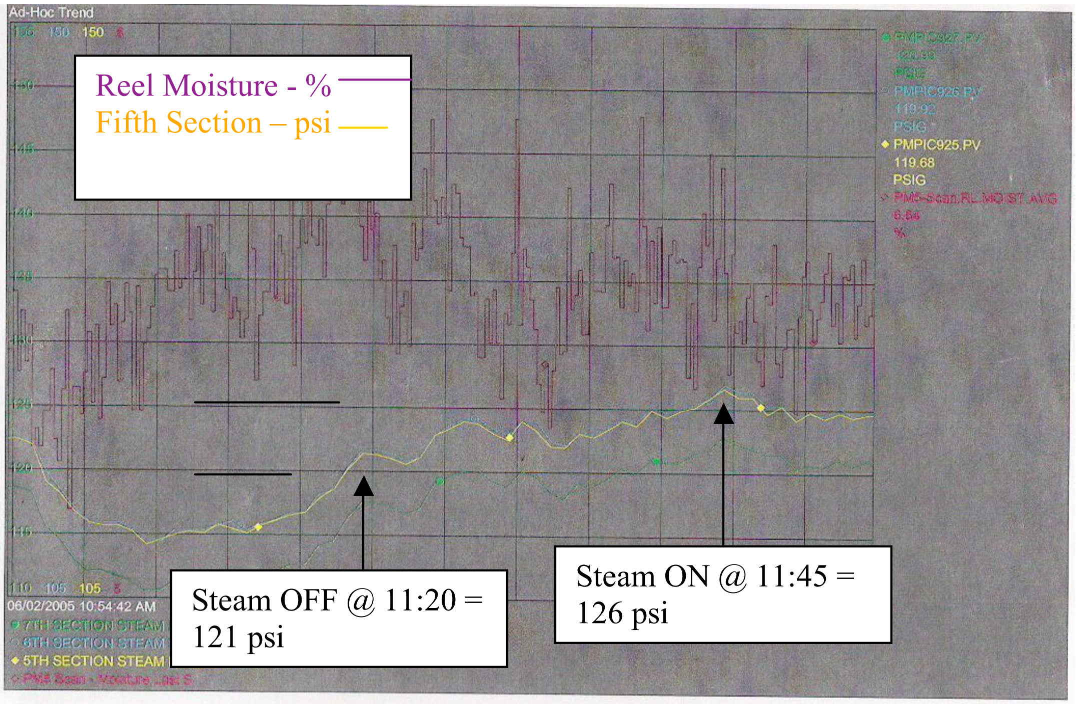
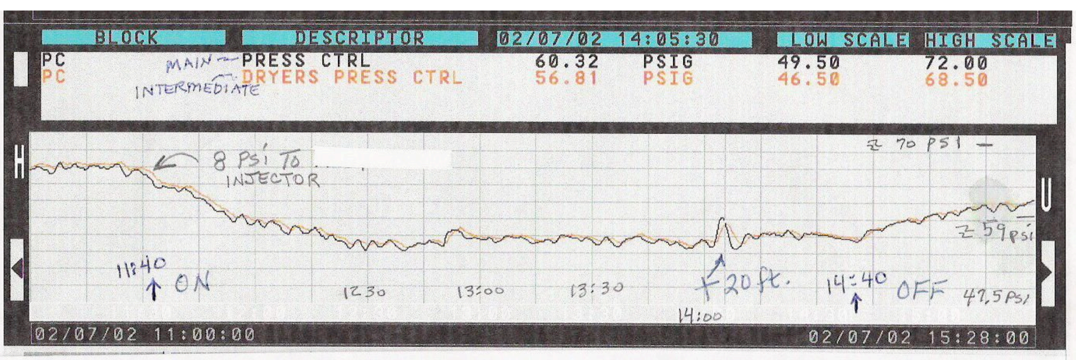


Figure 12 - Machine direction moisture variability can mask the benefits of a steam shower.

By contrast, the dryer steam printout of Figure 13 and temperatures of Figure 14 cleanly illustrate the value of heating the pickup fabric on this old machine making 100% recycled corrugating medium. Fabric moisture surveys and uhle box weir discharge flows are also valuable for determining the benefit of a steam shower heating a press fabric since they are not as subject to machine direction variables upstream as dryer steam monitoring.



- Steam supply to the Steam Injector over the Pickup felt Uhle box was turned on at about 11:35 AM. at which time steam pressure in the intermediate and last dryer sections automatically decreased. In one hour it dropped from an average of 62.5 to 56.5 psi. (10%) .
- At about 2:10 PM machine speed was increased by 20 fpm.
- Steam to the Injector was abruptly turned off at 2:40 PM and over the course of one hour steam pressure went up to an average of 65.5 psi vs. 55.5 psi (more than 15%!)
- It would appear that the suction pickup is running much more efficiently with the hotter felt.

Exhibit #13 – Dryer pressure demand by intermediate and last sections dropped from 62.5 psi to 56.5 psi (10%) when steam was supplied to steam shower over pickup felt uhle box. Note that turning steam ON had a greater immediate affect than turning it OFF since the fabric was cleaner.

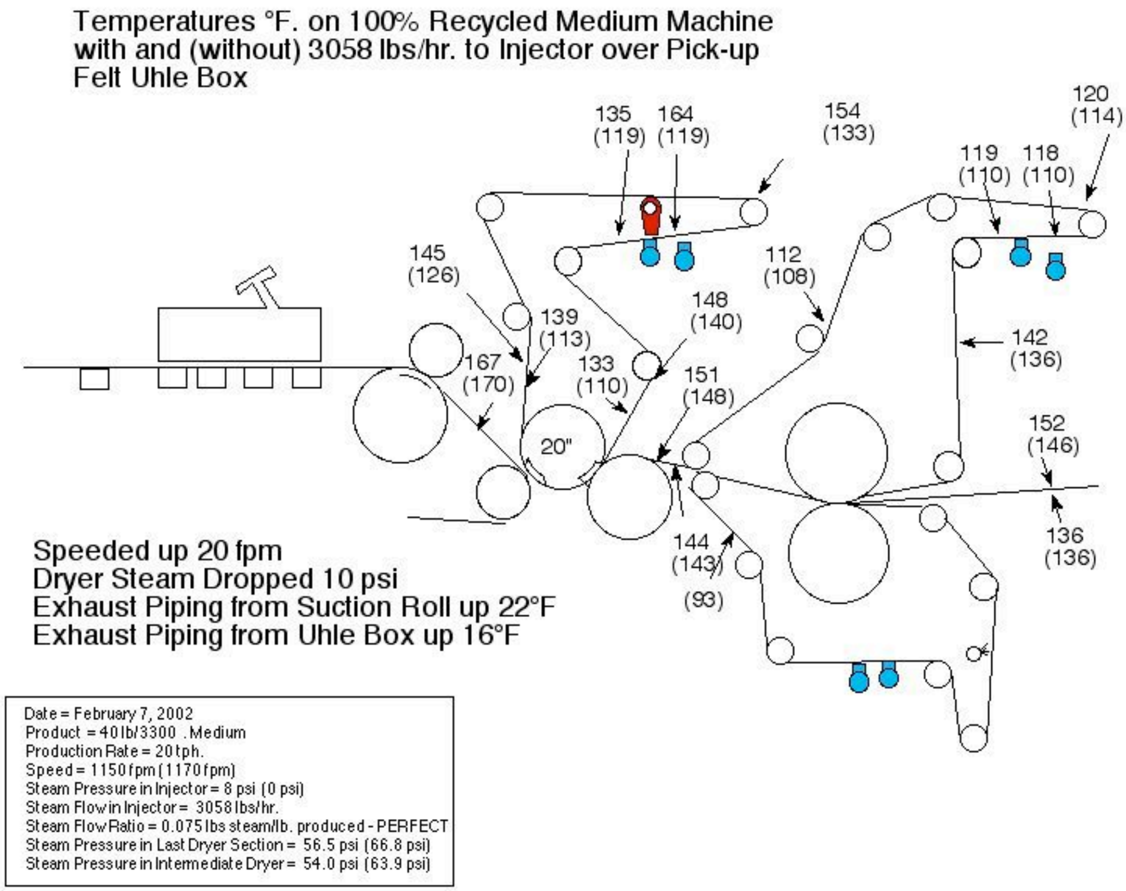


Figure #14 - System temperatures increased with steam supply to press fabric steam shower.

Documenting the value of a steam shower heating a press fabric is often more difficult than documenting the value of heating the sheet directly for several reasons. Firstly, heating the fabric is not as efficient as directly heating the sheet since, except in special situations such as a flooded press nip, the press fabric is not the determining factor in press nip water removal. The primary goal of heating a press fabric is to clean it and extend felt life, not necessarily increase production or remove steam from the dryer. As illustrated by the dryer load printout of Figure 13, the effect on dryer steam usage caused by abruptly turning a fabric steam shower off is not as obvious as when first turning steam on since the felt has already been cleaned and requires some time to fill back in. The benefit from heating a press fabric is better determined over a period of days or weeks, not hours and its value often comes down to a “gut feel” on the part of the operators that runnability or fabric life is improved enough to justify the inefficient application of steam.

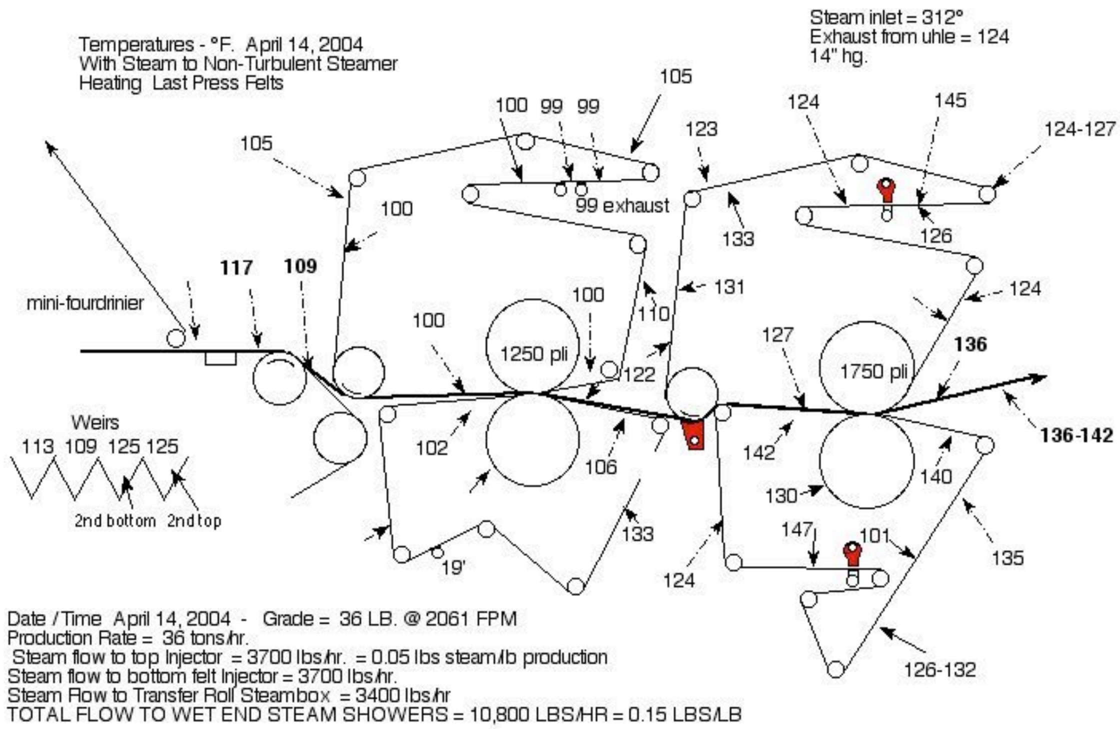


Figure 15 – Heating the last press fabrics allows use of the steam shower under the transfer roll. The sheet temperature entering the dryer is 30°F higher with steam application than without.

One special situation where heating a press fabric will reveal steam savings is when a cold fabric prevents use of a more efficient steam shower heating the sheet. This is the case on the machine illustrated in Figure #15. This 100% recycled linerboard machine found that heating the sheet with the steam shower mounted under the transfer roll caused excessive transfer of stickies to the cooler second press fabrics. Heating the last press fabrics with steam showers over the uhle boxes allows them to use the steam shower to heat the sheet directly and increase production. This mill has also documented and reported dryer steam savings when using the fabric steam showers alone but not to the extent of the combination of all three[7].

SUMMARY AND CONCLUSIONS

Steam showers may remove more steam from the dryer than they use but they must be properly designed, positioned, operated and evaluated. The energy efficiency of a steam shower determined with energy balances and "rule of thumbs" is often different than the efficiencies measured while operating due to interrelated operating variables such as increased water removal at one nip resulting in decreased water removal by another nip. Use of a steam shower often allows for changes to other papermaking operating criteria such as refining, press loading, showering, vacuum balances and energy inputs. The best opportunities for steam savings with steam showers are generally on machines running cool wet end system temperatures and the first amount of steam (web temperature increase) applied by a steam shower will typically do the most good. Water removal from the web closely follows the viscosity curve of water and there are diminishing returns from second and third steam showers on a given machine. The benefits obtained from high, inefficient steam flows are often justified by improved product quality, quantity and machine runnability. It is unfair to use steam economy alone when justifying the purchase of a new steam shower since the payback from increased production far exceeds the added cost of steam. Documentation of steam shower performance depends on a mill's monitoring equipment. The personnel running the machine should be trained and encouraged to experiment and optimize existing steam showers.

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