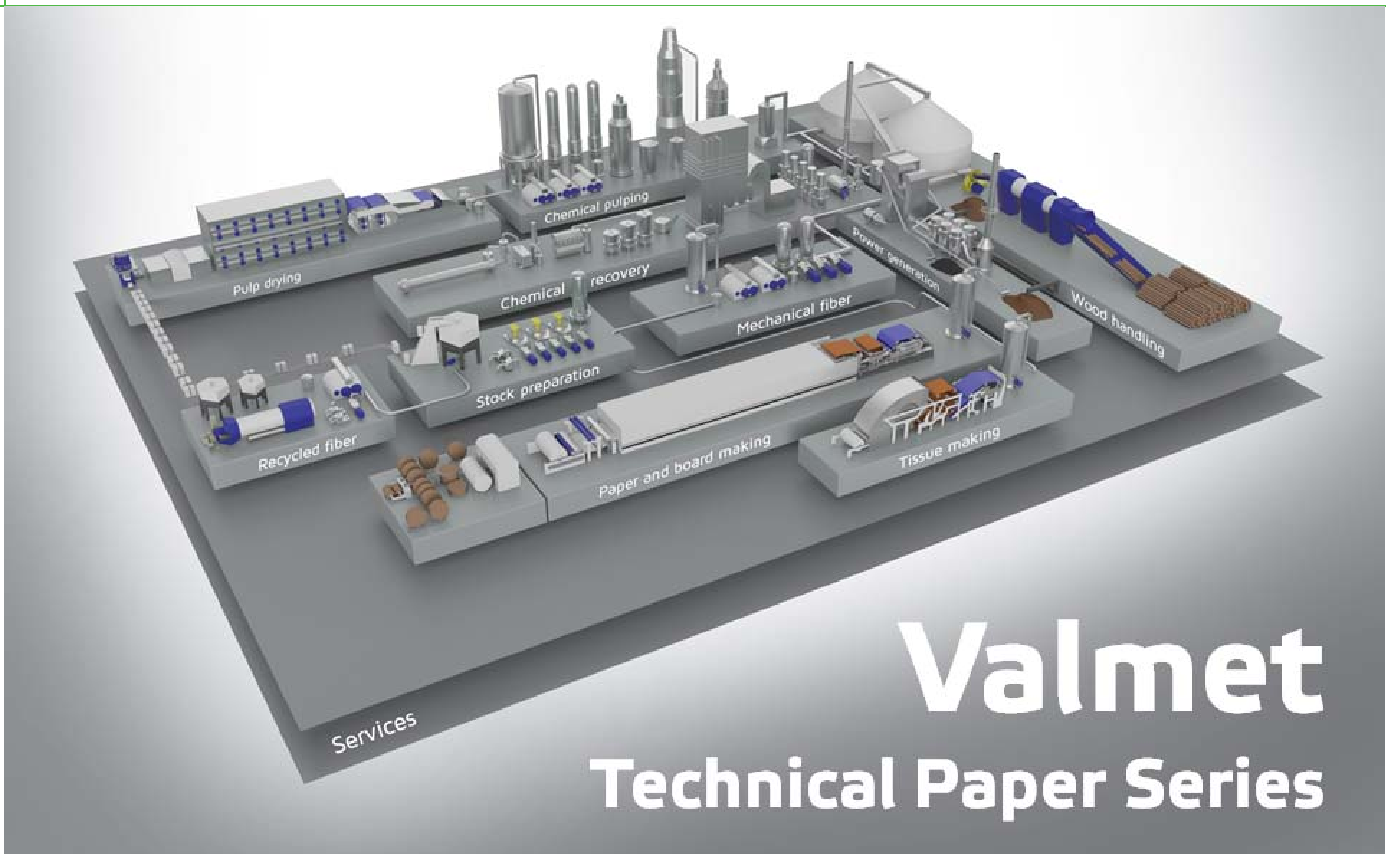

Flotation Drying of Coated Grades

Executive Summary

Coating drying is expensive. A great deal of energy is needed to effectively evaporate sufficient water to dry the coating. In terms of the operating costs of coating drying there are two important factors; 1) the specific energy consumption in the drying and 2) the price of the energy source used in the dryers. Different energy sources, for example natural gas, LPG gas, medium or low pressure steam and electrical power are generally used in the coater dryers.

While traditional drying has been successful, recent developments have taken the coater drying process to a new level; offering substantial savings never before available.

The latest air nozzle technology, combined with flotation dryers for coated paper and board, are examined in this paper. Case studies are presented to illustrate examples of state-of-the art technologies used today in coating drying, and the significant benefits these new components provide in reducing energy, improved finish quality, carbon footprint reduction, increased operating efficiency and improved overall mill profitability.

Overview of flotation drying

The coating process at a paper or board mill typically involves four steps:

1. applying the coating to the base paper on one or both sides (e.g. jet, curtain, film, short dwell)
2. metering the coating (e.g. blade, rod)
3. drying the coating (e.g. dryer cylinders, infrared heaters, impingement/flotation dryers)
4. finishing the sheet (e.g. supercalender or soft calender)

Step 3, the topic of this paper, drying of coated paper - requires the efficient movement of heat from a drying source to the coated paper. This heat movement from a warm substance to a cooler one happens via conduction, convection or radiation.

In the serpentine drying section of a paper machine, conduction is used to move heat from the dryer cans to the felts supporting the sheet. Natural convection movement of heat occurs when hot air rises, but this is typically aided in paper mills by fans/blowers forcing the convection to occur more rapidly. In the case of infrared (IR) dryers, very hot IR elements emit electromagnetic waves and heat the sheet via radiation. Drying of coated grades in paper mills is accomplished by dryer cylinders, forced air or infrared radiation, or a combination of the three types of heat movement.

In the case of forced air, there are two main dryers currently used for coating, similar in operation. For webs requiring only a single side coating, with the sheet supported by rolls on the other side, single-sided air impingement dryers are used. However, for webs that are two-side coated (C2S), and perhaps need to change direction shortly after being coated, a flotation dryer is necessary.

A flotation dryer is comprised of two impingement dryers, one on each side of the sheet. Air is fed into the dryers from the drive side of the machine, with the majority of the air being recirculated. The extra air (10-20%) comes either from the machine room or outside and is preheated. The recirculating air includes a higher than desired level of water vapor, removed from the sheet, and must be dried before re-entering the flotation dryer.

Typically, air dryers are heated with gas burners or steam coils, depending on the needed temperature, investment capital available and cost of energy. The steam pressure determines the maximum temperature available from a steam-heated dryer. Gas burners generate higher temperatures.

Air temperature is controlled by the operator, who can also control the air velocity. Alternatively, these controls can be automated. Too low of an air speed and the drying process is insufficient. Too high of an air speed can cause binder migration.

The air coming from the flotation dryers is directed at the paper via holes or slots in specially designed nozzles. In the case of impingement nozzles, a very efficient heat transfer mechanism, the air is pointed perpendicularly to the sheet, thus penetrating the barrier layer of air/vapor that the sheet carries with it. In the case of Valmet's PowerFloat nozzle a combination of normal flotation nozzles and impingement nozzles are used, providing a very high evaporation rate.

Flotation dryer development for coated grades

Coating drying is expensive. A great deal of energy is needed to effectively evaporate sufficient water to dry the coating. In production of coated paper or board, the amount of water evaporated in the coater dryer section is typically 0.1 to 0.2 ton H_2O per ton of produced paper or board. In terms of the operating costs of coating drying there are two important factors; 1) the specific energy consumption in the drying and 2) the price of the energy source used in the dryers. The specific energy consumption in the coater dryer section can vary from 4,500 to 10,000 kJ/kg evaporated water, depending on the drying concept, dryer adjustments and other operating parameters. Different energy sources, for example natural gas, LPG gas, medium or low pressure steam and electrical power are generally used in the coater dryers. While traditional drying has been successful, recent developments have taken the coater drying process to a new level; offering substantial savings never before available.

Air flotation or impingement coating drying is not a new concept. The operation and benefits of impingement drying are well understood; to the point where air drying is very much the norm in the industry. In the simplest terms, hot dry air is simply blown onto the wet coating thus raising the coating temperature to a point where water is evaporated from the sheet, leaving a relatively dry coated finish. The basics are simple. The challenges however are significant when one considers the many variables and influences that must be considered; which include:

- machine performance, geometries and limitations (draws, wrap angles, trim, speed)
- base sheet properties (basis weight, moisture, furnish, porosity, pre-coating, etc.)
- coating properties (chemistry, solids, coat weight(s))
- sheet/coating quality (CD and MD uniformity, marking, mottle, etc.)
- energy
- runnability and machine efficiency
- maintenance and service
- cost (capital, operating, maintenance)

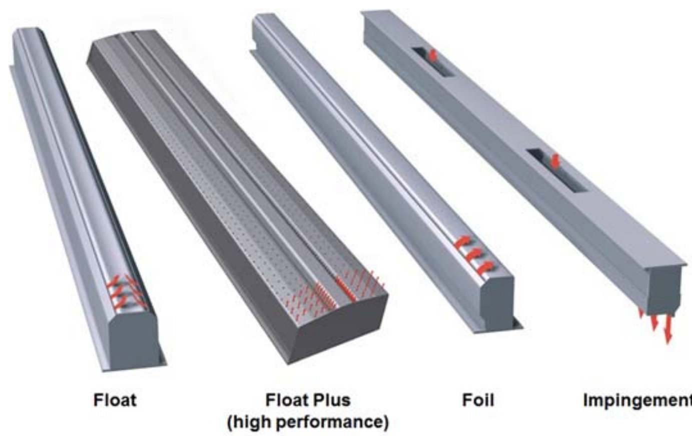

Figure 1. Air nozzle development

Recent developments in air dryer technology have significantly enhanced dryer performance. Specifically, new nozzle designs have dramatically improved drying effectiveness, namely doing more (better) drying using less energy.

Figure 1 illustrates the history of nozzle development. Early nozzles were relatively simple foils with a single air slot. Later nozzles typically included a double slot (float) arrangement to improve sheet flotation and drying performance. The most recent, and state-of-the-art designs include a much larger nozzle profile that supports and dries the sheet over a greater area. This improved design (**Figure 2**) has a significant effect on the dryer's ability to deliver energy to the sheet, more effectively; thus saving energy.

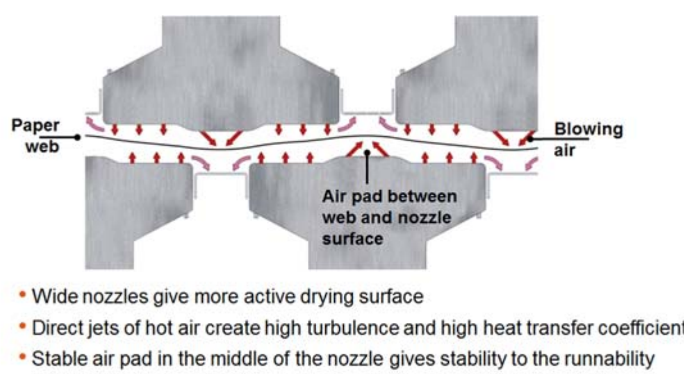

Figure 2. High performance float nozzle operating principles

Figure 3 illustrates the comparison between traditional double slotted nozzles, versus a new high performance design.

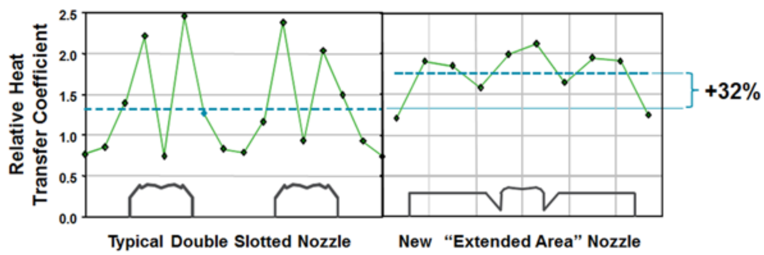

Figure 3. Nozzle comparison: double slotted vs. new nozzle

Over approximately the same (MD) cross sectional area, with the nozzles operating at the same temperature (200 °C) and blowing velocities (50 m/s), the new nozzle design performs much better (approximately 32%) in terms of average heat transfer coefficient. This improvement in heat transfer translates into significant savings in terms of energy and operating costs. In addition, the more uniform air distribution across the nozzle face offers significant advantages, namely:

- better sheet support (runnability, less marking)
- more even drying (sheet quality)
- reduced maintenance (less coating buildup)

This new nozzle design provides significant benefits and new opportunities in coater drying.

Air bar development (case study)

The true test of any new design is in a production situation. A side-by-side or on/off test is best, in order to demonstrate and quantify the performance of new technology relative to existing alternatives. For the purposes of this study, an existing machine was (partially) retrofitted with new dryer nozzles, thus providing the opportunity to do a true "before/after" comparison. The machine in question is a production capacity off-machine coater (OMC) (**Table 1** & **Figure 4**).

Machine	Coater #1 (bottom)	Coater #2 (top)	Coater #3 (top)	Coater #4 (bottom)
Fine Paper (LWC)	Coat wt: 7.97#/ream @63% solids	Coat wt: 8.19#/ream @63% solids	Coat wt: 7.16#/ream @63% solids	Coat wt: 7.65#/ream @63% solids
3700 fpm	Gas IR	Gas IR	Gas IR	Gas IR
150" trim	2 Air Dryers	2 Air Dryers	1 Air Dryer	1 Air Dryer
67.95 #/ream	2 steam cylinders	2 steam cylinders	4 steam cylinders	7 steam cylinders
3.28% moisture (base)				5.35% moisture (final)

Table 1. Machine data for off-machine coater used in case study.

In order to quantify the nozzle performance, baseline data was compiled for the existing machine prior to the rebuild. Similar data was then recorded post-rebuild for comparison.

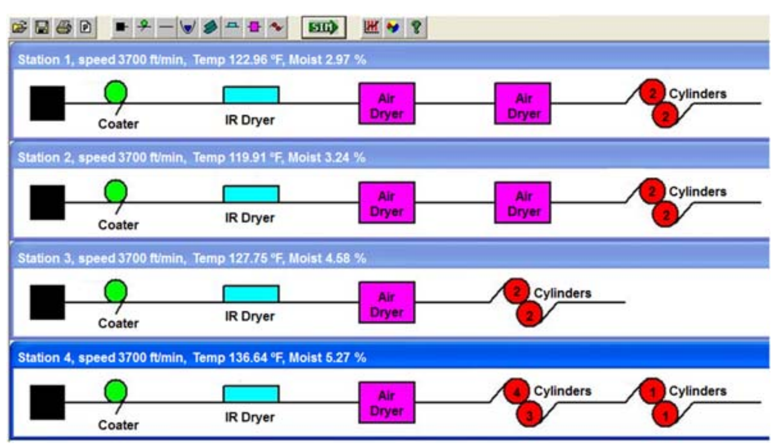

Figure 4. Computer model of off-machine coater

Simulations

Prior to the rebuild, extensive computer modeling was done to simulate comparative drying performance. This provided an opportunity to project the expected savings and verify the project feasibility. Pre- and post-rebuild simulations are shown in **Tables 2** and **3**.

Energy Calculation Summary – Simulation projection - All Dryers with Existing Air Bars
Based on production data taken April 2009

Speed	3,701 ft/min	1,128 m/min	Operating days per year 350	*Gas Cost* *$8.00 / million BTUs*
Trim	152.8 in	3,881 mm	% Operating efficiency 85	*Electrical Cost* *$400 / HP / year*

Coater 1

Gas IR			**Dryer 1**			**Dryer 2**		
Abs. Energy	792 MBH	232 kW	Abs. Energy	2,065 MBH	605 kW	Abs. Energy	1,993 MBH	584 kW
Evaporation	238 lb/hr	108 kg/hr	Evaporation	1,217 lb/hr	552 kg/hr	Evaporation	1,655 lb/hr	751 kg/hr
			Imp Temp	498 F	259 C	Imp Temp	511 F	266 C
			Imp Vel	9,820 ft/min	49.9 m/s	Imp Vel	9,940 ft/min	50.5 m/s
Gas Cons.	1,898 MBH	556 kW	Gas Cons.	3,430 MBH	1,005 kW	Gas Cons.	3,404 MBH	998 kW
			Elect Cons	86 HP	64 kW	Elect Cons	86 HP	64 kW

Coater 2

Gas IR			**Dryer 3**			**Dryer 4**		
Abs. Energy	793 MBH	232 kW	Abs. Energy	1,939 MBH	568 kW	Abs. Energy	1,768 MBH	518 kW
Evaporation	325 lb/hr	147 kg/hr	Evaporation	1,114 lb/hr	505 kg/hr	Evaporation	1,699 lb/hr	771 kg/hr
			Imp Temp	505 F	263 C	Imp Temp	519 F	271 C
			Imp Vel	8,840 ft/min	44.9 m/s	Imp Vel	8,070 ft/min	41.0 m/s
Gas Cons.	1,898 MBH	556 kW	Gas Cons.	2,973 MBH	871 kW	Gas Cons.	2,846 MBH	834 kW
			Elect Cons	71 HP	53 kW	Elect Cons	57 HP	43 kW

Coater 3

Gas IR			**Dryer 5**		
Abs. Energy	443 MBH	130 kW	Abs. Energy	1,488 MBH	436 kW
Evaporation	201 lb/hr	91 kg/hr	Evaporation	967 lb/hr	439 kg/hr
			Imp Temp	463 F	239 C
			Imp Vel	8,720 ft/min	44.3 m/s
Gas Cons.	1,253 MBH	367 kW	Gas Cons.	3,006 MBH	881 kW
			Elect Cons	59 HP	44 kW

Coater 4

Gas IR			**Dryer 6**		
Abs. Energy	221 MBH	65 kW	Abs. Energy	1,635 MBH	479 kW
Evaporation	157 lb/hr	71 kg/hr	Evaporation	1,348 lb/hr	611 kg/hr
			Imp Temp	517 F	269 C
			Imp Vel	8,050 ft/min	40.9 m/s
Gas Cons.	633 MBH	185 kW	Gas Cons.	3,831 MBH	1,123 kW
			Elect Cons	45 HP	33 kW

Total Energy Consumption from Gas	*25,173 MBH*	*Gas Cost*	*$1,437,858 /year*
Air Dryer Gas Consumption	*19,490 MBH*	*Electrical Cost*	*$161,405 /year*
Total Water Evaporated	*8,922 lb/hr*	***Total Cost***	*$1,599,264 /year*
Gas Energy Consumption per lb Water Evap.	*2,821 BTU/ lb H_2O*		

Table 2. Drying simulation result: Pre-rebuild

In simulating the drying, it is important to consider the entire drying process and all of the associated variables. Changing the drying at one point will have a ripple effect through the entire process, thus it is critical to look at the process as a whole and not in isolation. This also provides opportunity to look at shifting drying from higher cost dryers (e.g. IR) to more efficient air dryers to realize the full potential of the dryer section. As illustrated in **Table 3**, the projected air dryer savings was 9.9%. Overall however, the dryer section savings were predicted to be slightly lower (7.6%) due to the machine configuration and shifting of the drying within the dryer section.

Energy Calculation Summary -- Dryers 5 & 6 with New Hi Performance Nozzles (From Simulation)
Based on production data taken April 2009

Coater 1

Gas IR			Dryer 1			Dryer 2		
Abs. Energy	792 MBH	232 kW	Abs. Energy	2,065 MBH	605 kW	Abs. Energy	1,993 MBH	584 kW
Evaporation	238 lb/hr	108 kg/hr	Evaporation	1,217 lb/hr	552 kg/hr	Evaporation	1,655 lb/hr	751 kg/hr
			Imp Temp	498 F	259 C	Imp Temp	511 F	266 C
			Imp Vel	9,820 ft/min	49.9 m/s	Imp Vel	9,940 ft/min	50.5 m/s
Gas Cons.	1,898 MBH	556 kW	Gas Cons.	3,430 MBH	1,005 kW	Gas Cons.	3,404 MBH	998 kW
			Elect Cons	86 HP	64 kW	Elect Cons	86 HP	64 kW

Coater 2

Gas IR			Dryer 3			Dryer 4		
Abs. Energy	793 MBH	232 kW	Abs. Energy	1,939 MBH	568 kW	Abs. Energy	1,768 MBH	518 kW
Evaporation	325 lb/hr	147 kg/hr	Evaporation	1,114 lb/hr	505 kg/hr	Evaporation	1,699 lb/hr	771 kg/hr
			Imp Temp	505 F	263 C	Imp Temp	519 F	271 C
			Imp Vel	8,840 ft/min	44.9 m/s	Imp Vel	8,070 ft/min	41.0 m/s
Gas Cons.	1,898 MBH	556 kW	Gas Cons.	2,973 MBH	871 kW	Gas Cons.	2,846 MBH	834 kW
			Elect Cons	71 HP	53 kW	Elect Cons	57 HP	43 kW

Coater 3

Gas IR			Dryer 5		
Abs. Energy	443 MBH	130 kW	Abs. Energy	1,355 MBH	397 kW
Evaporation	201 lb/hr	91 kg/hr	Evaporation	1,010 lb/hr	458 kg/hr
			Imp Temp	311 F	155 C
			Imp Vel	8,720 ft/min	44.3 m/s
Gas Cons.	1,253 MBH	367 kW	Gas Cons.	2,159 MBH	633 kW
			Elect Cons	80 HP	59 kW

Coater 4

Gas IR			Dryer 6		
Abs. Energy	223 MBH	65 kW	Abs. Energy	1,474 MBH	432 kW
Evaporation	151 lb/hr	69 kg/hr	Evaporation	1,337 lb/hr	607 kg/hr
			Imp Temp	342 F	172 C
			Imp Vel	8,050 ft/min	40.9 m/s
Gas Cons.	633 MBH	185 kW	Gas Cons.	2,753 MBH	807 kW
			Elect Cons	54 HP	40 kW

Total Energy Consumption from Gas	*23,248*	*MBH*	*7.6% Decrease*	*Gas Cost*	*$1,327,909 /year*
Air Dryer Gas Consumption	*17,566*	*MBH*	*9.9% Decrease*	*Electrical Cost*	*$173,206 /year*
Total Water Evaporated	*8,947*	*lb/hr*		*Total Cost*	*$1,501,116 /year*
Gas Energy Consumption per lb Water Evap.	*2,598*	*BTU/ lb H_2O*			

TOTAL SAVINGS PER YEAR: $98,148 **CONSERVATIVE ESTIMATE: $90,000**

Table 3. Drying simulation result: Post-rebuild estimate

Dryer rebuild

By maintaining the same dryer air volumes and temperatures (or less) all of the existing ancillary equipment (e.g. ductwork, fans, burners, instrumentation, etc.) could be reused, saving considerable cost and downtime; thus providing a very attractive return on investment. Based on the projected return (e.g. energy savings <3yr ROI), plus the opportunity to improve sheet quality and runnability (e.g. machine efficiency), the decision was made to rebuild the two oldest dryers (#5 & 6), by using the latest generation air bar technology.

The two existing air flotation dryer hoods were modified to accommodate the new air bar technology. New return air screens were also installed between the air bars and around the internal perimeter of the dryers (**Figure 5**). To fully optimize the two dryers, additional repairs were also made to the dryer's air supply and exhaust systems. The entire dryer rebuild process, for both dryers, took less than 72 hours.

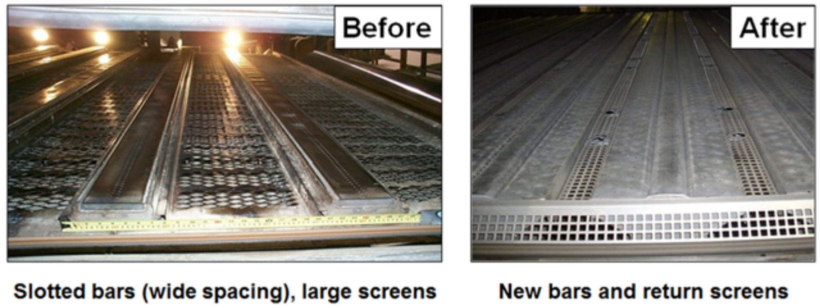

Figure 5. Dryer rebuild: before and after photos

Conclusions of air bar development case study

Figure 6 illustrates the initial results of actual production conditions measured before and after the dryers were rebuilt with the new air bars. Post rebuild testing confirmed savings due to improved nozzle performance in the order of 10% (compared to 7.6% predicted). An additional 5% savings was realized principally due to the refurbishment and optimization of the existing equipment, controls and air systems (e.g. rebalancing, dryer cleaning & alignment, etc.).

This next generation of air bar technology provides significant benefits in terms of:

- Superior heat transfer resulting in greater operating efficiency
- Improved sheet runnability
- Relatively simple retrofit (minimal investment, little down time)

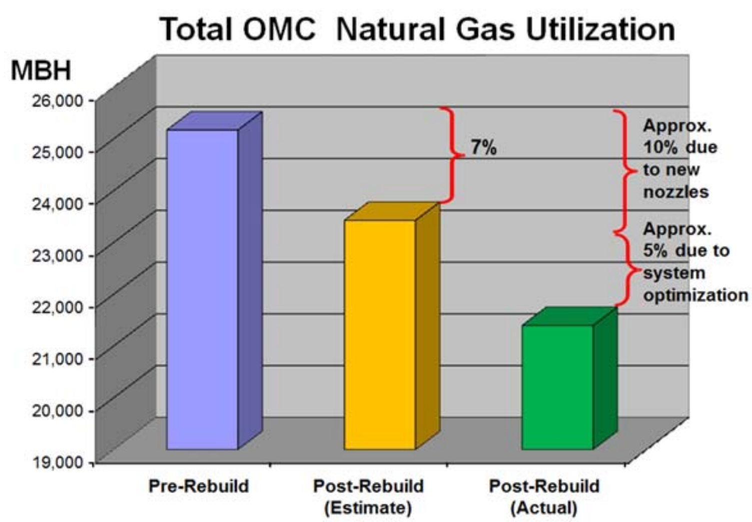

Figure 6. Energy savings with new air bars

Drying strategy (case study)

Drying is a critical part of the quality formation process of coated paper. In support of this, many studies have been undertaken to look at how drying strategies affect quality, and to confirm the best drying strategy to use. The most common drying strategy used today is the so-called "high-low-high" theory. The consensus of these earlier studies has been that the drying rate during the "critical" drying phase is the main factor contributing to mottle (e.g. unevenness of the print surface). Uneven binder migration has been assumed to be the reason for uneven surface properties, leading to non-uniform printing. No conclusive evidence however for this has been found in surface binder content analysis. Unfortunately, many of the earlier studies were limited due to the layout of the pilot coaters. Generally, the pilot machine configurations included an infrared (IR) dryer, free draw, and air dryer. If part of the coating has been consolidated in the IR dryer or free draw, the rest of the coating has to be consolidated in a similar fashion (low evaporation rate) in order to reach the same coating structure. This leads to a failed conclusion, e.g. that the best strategy is that a low drying rate has to be maintained in the later part of the drying section (high-low-high strategy) (**Figure 7**) in order to maintain coating structure.

Hi-intensity air dryer

Given the limitations associated with the earlier studies, a new study was undertaken to see the effects in coating quality and binder gradients if the coating is dried using a single-sided high intensity dryer. Utilizing newly developed nozzle designs and a hi-intensity dryer system, it was possible to test the "all-high" drying hypothesis (**Figure 8**) using an all air dryer, in place of traditional IR.

A broad cross-section of grades (**Table 4**) and coating colors (**Table 5 next page**) were tested as part of the coating/drying trials.

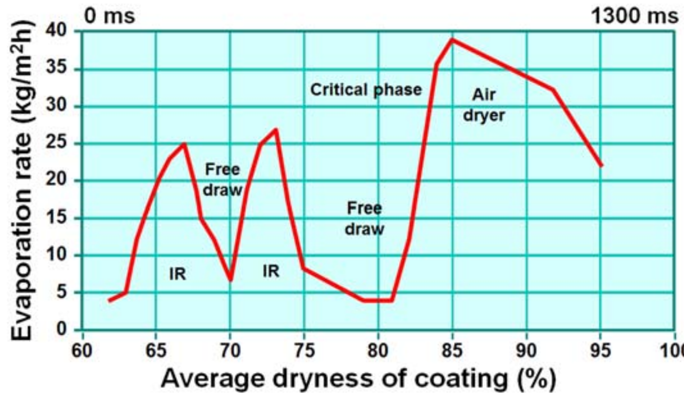

Figure 7. Traditional "high-low-high" drying strategy

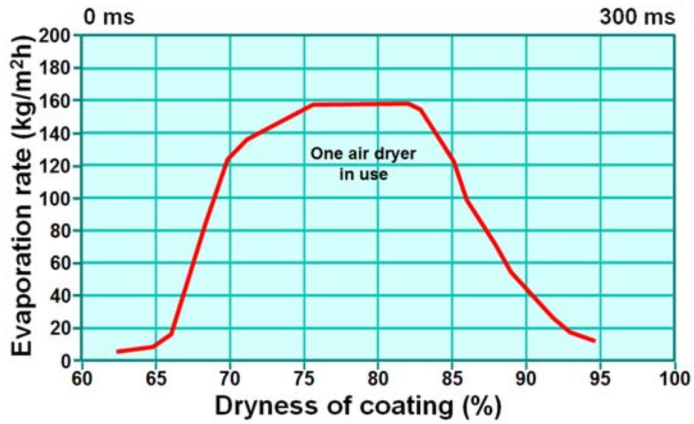

Figure 8. New "all-high" drying strategy

Paper grade	Base paper	Precoating (g/m^2)	Top coating (g/m^2)	Top coat color	Speed (m/min)
Triple coated WF	WF1 80 g/m^2	8+8+12+12	12+12	2	1500
Double coated WF	WF1 80 g/m^2	8+8	12+12	2, 3	1000
LWC	LWC1 40 g/m^2	None	12+12	2, 7	1000
LWC	LWC2 45 g/m^2	None	12+12	8	1000
Double coated board	Board 190-215 g/m^2	10 (TS)	12 (TS)	5, 6	500

Table 4. Trial conditions - grades

Color	2	3	4	6	7	8
Fine clay (HG 90)	70	70	30	70		
Ground fine carbonate (HC 90)	30	30	70	30		
Delaminated clay (Astraplate)					100	100
SB latex A, Tg +10	12		12		12	6
SB latex B, Tg +15						
SB latex C, Tg +0		12				
VinAcetAcrylic latex D, Tg +15				14		
CMC	0.8	0.8	0.8	0.8	0.8	0.8
Oxidized Starch						6
Hardener	0.1	0.1	0.1	0.1	0.1	0.1
Lubricant	0.5	0.5	0.5	0.5	0.5	0.5
Optical brightener	0.2	0.2	0.2	0.2	0.2	0.2
Solids	62	62	62	63	60	60

Table 5. Trial conditions - top coating colors

The pilot trials on LWC, WF and board were conclusive in confirming that a single hi-intensity air dryer, in place of IR, could net excellent results including:

- higher drying (evaporation) rates
- mottle, gloss and smoothness improved when effective air drying is included immediately following the coating station (**Figures 9** & **10**)
- air drying is equal or superior to IR in terms of paper quality.

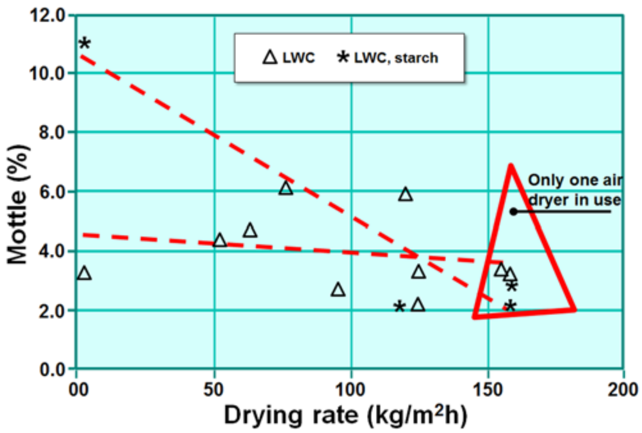

Figure 9. Test results: Reduced mottle - single hi-intensity dryer

This series of pilot trials confirmed that a very uniform surface porosity distribution was possible using extremely high evaporation rates and a single dryer, resulting in better print characteristics. From this, it was possible to prove that a "high-high-high" air drying strategy could produce very even porosities resulting in less mottling, better gloss, and increased smoothness.

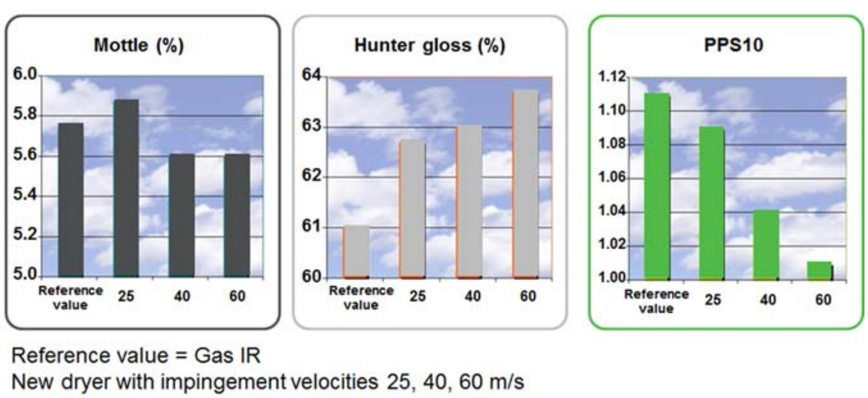

Figure 10. Test results: Mottle, gloss and smoothness

Dryer rebuild

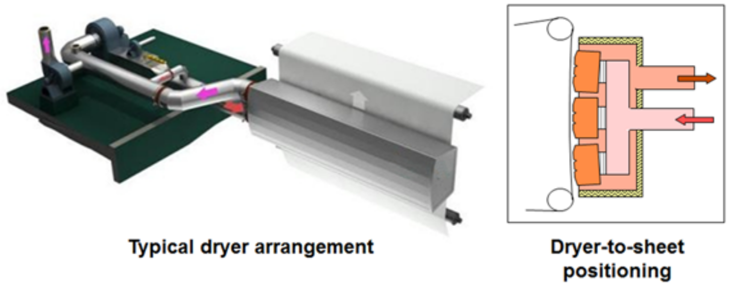

Figure 11. New hi-intensity air dryer

Building on the success of the pilot trials, this new high-high-high drying strategy was implemented on a production machine. As part of the rebuild e.g. two (2) existing gas fired IR dryers were replaced with two (2) new hi-intensity air dryers. The new dryers fit into the exact location of the IR dryers, thus eliminating the need to reconfigure the machine and the associated costs. Utilizing new nozzle designs, the single sided hi-intensity dryer system is very similar to a traditional air dryer configuration including, a supply fan, burner, air dryer, combustion fan, make-up air and exhaust (heat recovery optional), as seen in **Figure 11**.

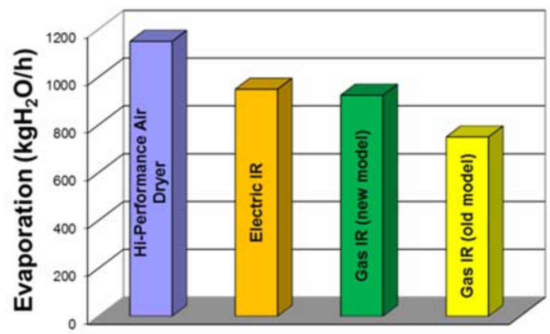

Figure 12. Relative evaporation rates

Results from the rebuild confirmed what was expected from the pilot trails in terms of sheet quality. In addition, significant benefits were also realized in terms of energy savings and operations. **Figure 12** illustrates the comparative evaporation rates between typical drying strategies. Operating at approximately 450 °C, 60 m/s the hi-performance dryers can deliver a significant amount of energy to the sheet. This increase results in approximately 20% more evaporation per square meter compared to traditional gas IR dryers; while maintaining runnability and sheet quality. In terms of drying efficiency (e.g. energy costs), the high-performance air dryer operates at close to 80% efficiency, compared to traditional IR at 35%.

Conclusions of drying strategy case study

Based on the results from this recent rebuild, the new hi-intensity dryer concept has proven to be successful in delivering:

- Energy savings, e.g. 60-80% drying efficiency with air drying, 25-40% with IR drying and reduced carbon footprint (50% less fuel burned= 50% less CO_2 formed)
- Higher drying capacity (more production potential)
- Much lower maintenance costs (approx. 0 with air dryers)
- Improved operating conditions, e.g. lower machine hall moisture and heat loads
- Equal or better paper quality (mottle, gloss, smoothness) compared to IR
- Lower web temperature
- Less water penetration
- Higher binder content on the paper surface
- Low investment costs/evaporation ($/$H_2O$/ft^{2}h) compared to IR
- Greatly reduced operating hazards (e.g. fires)

Case Study: Optimization of air flotation dryers at NewPage Escanaba

NewPage Escanaba was experiencing drying issues on their #1 Off Machine Coater. Besides looking to eliminate a wet steak problem, they were also looking to improve runnability and reduce energy usage. It was agreed that a performance evaluation of their #1 dryer group was necessary.

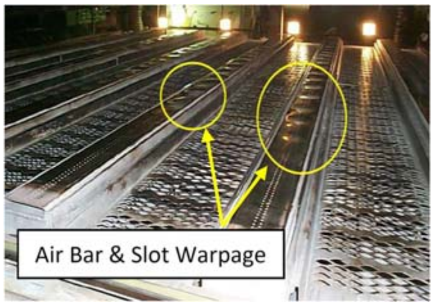

Figure 13. Warped bars (pre-rebuild) and return screens

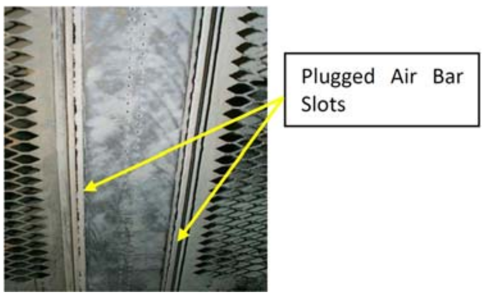

Figure 14. Plugged air bar slots (pre-rebuild)

This performance evaluation included the entire drying section including the steam cans, IR dryers, and the air flotation dryers. Upon completion of the study, recommendations were made with respect to all facets of drying. The air flotation dryers offered the greatest potential for improvement (**Figures 13** & **14**) and are the focus of this case study.

The dryers were originally supplied with a commonly used air bar design (air flotation nozzles). The existing air bars were located on 20" centers. The dryers are heated using direct fired natural gas burners. The mill's immediate concerns were issues relating to both sheet quality and the operation on their two oldest air flotation dryers. Any improvements to the air flotation dryers' operation needed to include energy savings through newer, more efficient technology.

The performance evaluation of the air flotation dryers confirmed that improvements to the dryers were required to address the drying issues the mill was experiencing.

Computer modeling of the drying process confirmed that this latest generation of air bar (flotation nozzle) technology would meet the operating requirements, e.g. better sheet quality, improved runnability, and reduced energy. This latest generation of air bar technology provides more effective heat transfer for the same volume of airflow than the existing air bars, and with better runnability. Better heat transfer means increased production for the same operating temperatures or reduced energy consumption for the present production rate. By maintaining the same air volumes and temperatures (or less) all of the existing ancillary equipment (e.g. ductwork, fans, burners, instrumentation, etc.) could be reused, saving considerable cost and downtime; thus providing a very attractive return on investment. Based on the projected return (e.g. guaranteed energy savings <3yr ROI), plus the opportunity to improve sheet quality and runnability (e.g. machine efficiency), the mill decided to rebuild the two oldest dryers, by installing this latest generation of air bar technology.

The two existing air flotation dryer hoods were modified to accommodate the new air bar technology. New return air screens were also installed between the air bars (**Figure 15**) and around the internal perimeter of the dryers. To fully optimize the two dryers, additional repairs were also made to the dryer's air supply and exhaust systems. The entire dryer rebuild process, for both dryers, took less than 72 hours.

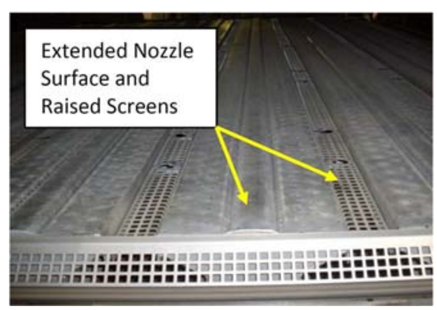

Figure 15. New air bars (flotation nozzles) and screens (post-rebuild)

A more typical expectation would be approximately 24 hours for each dryer. Once the dryer hoods were reassembled and realigned, the air supply to the dryers was rebalanced.

Upon start-up, Mill Operations noted that while operating at the same process conditions, as those applied prior to the rebuild, they were actually over drying the sheet/coating. As such, they reduced the amount of IR drying by shutting off one row of emitters. Since rebuilding dryers #5 and #6, operations has reported "Improved runnability with the elimination of sheet marking, easier clean-up, and no sheet breaks associated with dryers #5 and #6."

According to Mill Operations, "We've eliminated drying imperfections previously associated with our #5 and #6 air flotation dryers. This latest generation of Air Bar Technology along with the dryer optimization has exceeded everyone's expectations in positive returns. We're saving thousands of dollars in natural gas costs each month since optimizing our air flotation dryers and retrofitting them with this new generation Air Bar Technology."

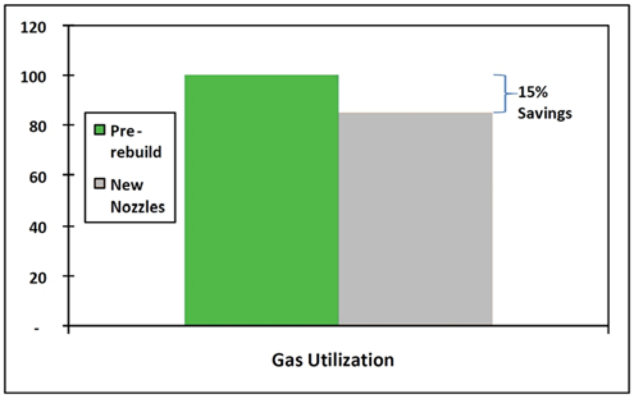

Figure 16. Average gas savings per air dryer (post-rebuild)

Figure 16 shows the initial results of actual production conditions measured before and after the dryers were rebuilt with the new air bars. Further savings have been realized through additional equipment optimization along with operational tuning of the remaining coater dryers, resulting in an additional 5+%. The mill is currently planning similar upgrades on more of their air flotation dryers, in the near future.

There are many mills today that have original air flotation dryers that are 10, 20, 30+ years old that are still operating. Many of these dryers are experiencing runnability issues (sheet marking, dragging, etc.), profile issues (wet streaks), or run inefficiently (high energy costs). As proven at this mill, this new generation of air bar technology provides benefits in terms of:

- Superior heat transfer resulting in greater operating efficiency
- Improved sheet runnability
- Heavier duty design for greater integrity and longer life
- Elimination of air bar gaskets, thus reducing maintenance cost
- No air bar slots that can change thus creating issues within your dryers
- Minimal capital investment, requiring little down time
- Compatible with any manufacturer's dryers.
- Simpler, faster clean-up

Significant savings in operating costs in coating drying

OptiDry Coat and OptiDry Turn air dryer families (**Figure 17**) are Valmet's air drying solutions for the best drying results and maximized energy efficiency. They offer over 50% energy savings compared with IR drying. Key components like Valmet Air Dryer Nozzles facilitate uniform and efficient evaporation with minimum energy consumption and excellent runnability.

Figure 17. OptiDry Turn and OptiDry Coat after OptiSizer coating station

Good for profitability – best for paper quality

Valmet has been focusing on the development of air drying systems for over three decades, as they are the unquestionable choice compared with IR drying when it comes to drying results, saving energy and the environment. Air dryers enable over 50% energy savings, which also has a direct impact on lowering carbon dioxide emissions and environmental load.

In air drying research, Valmet has concentrated on two areas: how to create a high-efficiency air dryer nozzle and the paper quality following the high-efficiency air drying.

High-evaporation efficiency with Valmet Air Dryer Nozzles

The common element for all Valmet air dryers is the Valmet Air Dryer Nozzle (**Figure 18**), giving high-evaporation efficiency for drying. Using these efficient air nozzles not only improves drying capacity, but also decreases energy consumption. These outstanding nozzles efficiently transfer the heat to the paper web so the temperature of the air returning from the drying – as well as the temperature of the dryer's exhaust air – is then lower. This results in less energy loss to exhaust air and better total energy efficiency.

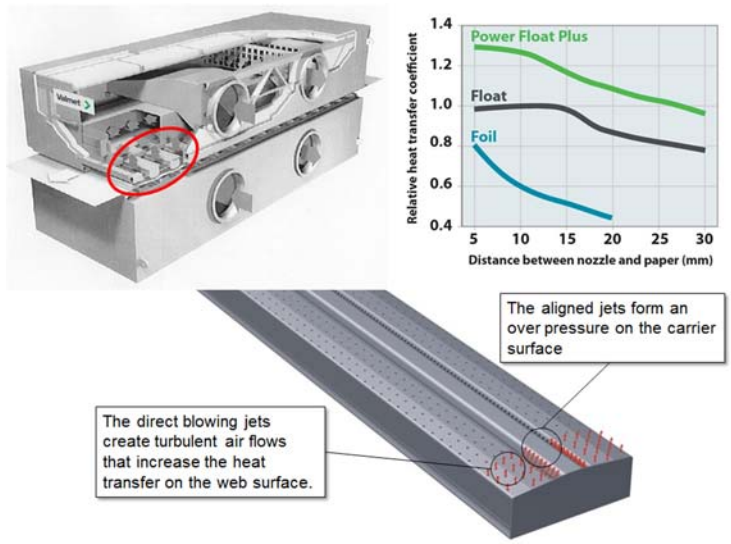

Figure 18. Valmet Air Dryer Nozzles increase drying effectiveness

Existing air dryers with old and less efficient nozzles of foil or float type can be upgraded by installing Valmet's patented Valmet Air Dryer Nozzles. These can easily be installed without changing the drying layout to both Valmet's and other manufacturer's air dryers.

Modern coating drying with high-efficiency air dryers

For a long time, it has been believed that infrared dryers were needed to ensure the quality of coated paper and board. Now after many years of research and several running references, we are convinced that when coated paper is dried with a high efficiency air dryer right after the coating station, the quality is at least as good as with infrared drying due to:

- Higher evaporation rate with lower web temperature
- Less water penetration
- Higher binder content on the paper surface

Operating costs of coating drying

As stated earlier, the operating costs of coating drying are affected by two factors: the specific energy consumption during drying and the price of the energy source used in drying. Comparing different dryer types, air dryers by far have the highest energy efficiency.

The energy efficiency of air dryers – defined as the energy transferred to the web divided by the energy used for dryer heating – is typically 70 to 75%, while for gas or electrically heated infrared dryers, it is typically 25 to 35%. This means that an air dryer needs only half the heating energy needed by an infrared dryer for the same amount of evaporation. With heat recovery, it is possible to reach over 80% energy efficiency.

Low life cycle operation costs

There are very few wearing parts in air dryers. So, maintenance costs are also much lower than in IR drying, where emitters or lamps must be changed every few years. Typically, with the IR dryers all lamps or emitters need to be changed within two to four years, requiring frequent investments and shutdowns.

OptiDry Coat air dryer family

The OptiDry Coat air dryer family (**Figure 19**) is the result of Valmet's proven expertise and commitment to air drying technology and is designed to increase the overall flexibility and efficiency of the drying process.

OptiDry Coat one- or two-sided air dryer | OptiDry Coat integrated air dryer | OptiDry Coat high intensity air dryer

Figure 19. OptiDry Coat air dryer family

In an air dryer, drying is performed by convection – by jets of hot air directed onto the sheet surface. Uniform, efficient evaporation with minimum energy consumption and excellent runnability is achieved by Valmet's air dryers. The drying process is optimized by controlling two parameters – nozzle air temperature and velocity.

The air dryer is designed to evaporate the water from coated paper and board, remove the evaporated water and recirculate a large portion of the impingement air. This maximizes the energy efficiency. Recirculating the air also minimizes the heat load, water vapor and volatile coating color compounds in the machine room.

OptiDry Coat one- or two-sided air dryer

OptiDry Coat is the basic model of all Valmet air dryers. It is available as a double-sided or one-sided model. In wide machines, the air dryer has a tapered shape to save space in the machine hall, so in the retracted position, the tending side height does not exceed the drive side height.

OptiDry Coat integrated air dryer

OptiDry Coat integrated air dryer is ideal for narrow- and medium-sized machines. It is available as a double-sided or one-sided model. OptiDry Coat integrated air dryer is quick to install during rebuilds with minimized downtime because the air circulation system, including fans and burners, is incorporated within the dryer modules. It is ideal for rebuilds where the available space for external air system is limited.

OptiDry Coat high intensity air dryer

The award-winning design of the OptiDry Coat high intensity air dryer has been developed for use in drying coated paper grades where an IR dryer has been traditionally used as a first dryer directly after the coating station. This special solution is designed to fit into the same space as an existing IR dryer, providing a huge improvement in energy efficiency, more evaporation capacity and better end product quality.

Numerous tests from pilot and production machines show that coated paper quality with respect to mottling, gloss and smoothness is as good or better compared with infrared drying. Also, significant improvements in working conditions in the coating station areas have been achieved by changing IR dryers to OptiDry Coat air dryers due to low heat and humidity loads into machine hall.

OptiDry Turn air dryer family

Valmet has combined the winning design of the TurnFloat air turn with the OptiDry Coat air dryer to create a shorter drying layout and better runnability for coating machines. OptiDry Turn air dryers simultaneously turn and dry the web during the sizing or coating drying process without touching the web itself (**Figure 20**).

Figure 20. OptiDry Turn air dryer family

The air turn part utilizes a pad of over-pressurized air generated by the air supplied between the web and the carrier surface. The web is supported on an air cushion and is turned without contact. In the OptiDry Turn air dryer, the air turn part gives the same benefits as the TurnFloat air turn itself:

- Constant nozzle-to-web distance in machine direction using a pressure equalization chamber that connects the perforated plates between the nozzles.
- Minimized soft wrinkles at air turn thanks to sectionalized air flow in cross-machine direction that adjusts impingement velocity of the air-turn nozzles in each zone.
- Constant clearance between air turn and web at varying web tensions with Auto Clearance Control, which adjusts the supply air flow to the right level.
- Reliable web tension indication calculated from pad pressure measurement.

Exceptional stability

The compact layout concept, without any free draws between the drying components, gives exceptional control of all air flows in contact with the web. The web is supported by air throughout the entire drying process. This results in much greater web stability than in layouts with uncontrolled free draws between the drying elements.

Uniform evaporation

The OptiDry Turn air dryer gives uniform drying through the drying "tunnel" and provides longer, more controlled dwell time in the air dryer. The result is more efficient and uniform drying without the typical temperature and evaporation peaks common in traditional coater drying layouts.

Numerous applications

The OptiDry Turn air dryer has allowed simultaneous web turning and drying for numerous applications over the last decades. It has been used in machines with all web widths, from pilot size machines to the world's widest machines, and for drying paper and board grades from 100% wood-containing to total woodfree, and from ultra-light to MWC.

OptiDry Turn two-sided

OptiDry Turn two-sided air dryer is a standard solution today for drying coating on both sides of the paper. It is a preferred solution in sizing and film coating processes.

OptiDry Turn integrated

OptiDry Turn integrated has been designed for narrow- and medium-sized machines. It is an ideal solution for rebuilds with minimized downtime requirements and space limitations on the drive side. The air circulation system, including fans and burners, is incorporated within the dryer modules.

OptiDry Turn one-sided

OptiDry Turn one-sided is specifically created as a solution for coated board. It is a one-sided air dryer application with high evaporation capacity simultaneously turning the web without contact. The OptiDry Turn one-sided air dryer simplifies the coater layout.

Case Study: OptiDry Coat high intensity air dryer replaces IR at Sappi Kangas PM4

In June 2007, two OptiDry Coat high intensity air dryers were started up after the coating stations at the Sappi Kangas PM4 fine paper machine in Finland, replacing old gas infrared dryers.

Mill Manager Anders Ek stresses that they did not want to invest in technology that would need to be replaced in a few years. Instead of buying new emitters for the IR dryers, they chose the almost service-free OptiDry Coat high intensity air dryers. He comments: "The greater drying capacity and energy-saving potential of the [OptiDry Coat high intensity] air dryers were very attractive and important features. The dryers represent a perfect solution for our needs."

Two years after the upgrade, Anders Ek notes that, "The machine gained more drying capacity and gas consumption decreased, just as Valmet had promised. Runnability is excellent, the dryers are easy to use and control, and they enable paper quality optimization. One thing that surprised us was the improvement in working conditions at the coating station. Our operators have reported an amazing change for the better."

Case Study: 50% energy savings with OptiDry Coat at Cartieri del Garda PM2

Cartieri del Garda installed a Valmet OptiDry Coat high intensity air dryer to replace their gas IR dryer after the precoating station on PM2. In this very tight layout, the mill makes coated fine paper with top coated grade weight of 150-400 g/m^2 and machine speed of 300-800 m/min. Valmet guaranteed energy savings of 48% of gas consumption.

The results were exceptional, starting with 50% gas savings even at high machine speed. Cartiere personnel were quite happy. According to Mill Production Manager, Antonio Di Blas: "50% gas savings, better paper quality, better working conditions, better availability, less maintenance costs – we got it all. Valmet impressed us with technical knowledge and with this exceptional dryer."

Coating Technical Manager, Vittorio D'Olif agrees: "Every goal of this rebuild was achieved. Gas consumption decreased 50% even though we increased our production speed by over 10%. Paper quality is better due to no picking and no stripes. This dryer is also easy to use and adjust."

Technical Manager, Tristano Rossi was pleased with Valmet's know-how: "Technical expertise of Valmet people in every step of the project from sales to the start-up was convincing, so the excellent end result is not a coincidence."

Case Study: Sappi Stockstadt mill upgrades to Valmet Air Dryer Nozzles

An up to 35% saving in coating drying energy means a significant investment payback for Sappi's Stockstadt mill. Sappi Fine Paper's Stockstadt mill in Germany made an ideal investment with the installation of high intensity air float Valmet Air Dryer Nozzles in an existing air dryer after the first coating station of the mill's OMC 2. The Beloit OMC 2, started up in 1992, produces wood-free coated grades with grammage ranging between 90 to 200 g/m^2. Up to 35% energy saving was achieved, bettering Valmet's guarantee, and, remarkably, this was soon after a short five-week delivery.

Sappi Fine Paper's decision was backed up by the fact that it has already achieved excellent results with previous installations of Valmet Air Dryer Nozzles at mills in Kirkniemi and Kangas in Finland. The coating dryers there have added extra drying capacity and enabled energy savings by eliminating the need for infrared drying.

The project was a simple retrofit project, not a drying system reconstruction. By replacing the original supplier's air nozzles with the new Valmet Air Dryer Nozzles much higher drying rates can be achieved and the opportunity to save a considerable amount of drying energy is possible. Valmet offers this flexible and practical solution for existing dryers supplied by a variety of vendors.

This saving is accomplished by shifting the bulk of the drying load from the existing gas-fired infrared dryer to the newly upgraded air dryer. Energy is used more effectively and efficiently in the air dryer than in the infrared dryer. To keep the project cost low, existing fans, gas burners and ductwork were kept in place.

Less than one year payback

Ulla Peura, Mechanical Engineer, explains that the project ROI, which was calculated as less than one year payback, was defined mostly by savings in natural gas consumption in the infrared dryer after the first coating station and replacing that drying capacity with more efficient air drying. Some important maintenance savings will also be made, since expensive infrared emitters will not need to be replaced from time to time. By comparison, the air dryer nozzles are essentially maintenance-free.

"It was important for us not to have to rebuild the air supply, exhaust systems, or gas burners. As a result, it was a simple project. We didn't have much time either, only five weeks and the timing was critical due to a shutdown on PM 2." Valmet responded with a five-week delivery from order to start-up within a three-day window in March 2010, so the results were achieved quickly.

With the upgraded air dryer providing extra drying capacity, 4 rows of infrared emitters could be switched off. The remaining two rows are used for cross-direction moisture profiling. Peura says the original guarantee of 28% energy savings was bettered and the total savings are up to 35% (**Figure 21**). She also notes that there is no effect on coated sheet quality.

OMC2 Superintendent Rainer Griesemer and Mechanical Engineer Ulla Peura agree: "…All of our expectations were met. We are very happy with this project and the savings we achieved."

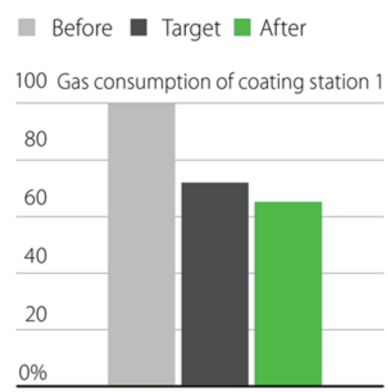

Figure 21. The original guarantee of 28% energy savings was bettered and the total savings are up to 35%.

OptiDry Profile air dryer – the first coating air dryer with moisture profiling

The earlier poor energy efficiency of IR dryers was accepted because of profiling needs. Now Valmet has introduced OptiDry Profile (**Figure 22**), a new profiling air dryer with simple construction and low operating costs to replace profiling IR dryers. It shares all the good qualities of OptiDry coating air dryers.

The dryer has excellent energy efficiency with an energy recovery system (OptiAir Recovery) and is environmentally friendly. OptiDry Profile offers efficient profiling with low web temperature and less water penetration to base paper.

OptiDry Profile (**Figure 23**) replaces IR for paper moisture profiling. It is based on temperature control, with a temperature difference of approximately 150 °C. Profiling occurs with different air temperatures in 300 mm profiling zones.

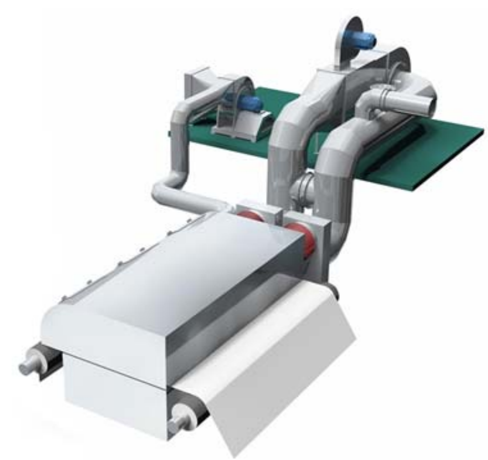

Figure 22. OptiDry Profile offers efficient profiling with all of the OptiDry air dryer benefits.

Stora Enso Kemi excellent results with OptiDry Profile

Stora Enso installed OptiDry Profile on their CM1 machine in the last air dry of this four station coating machine in September 2012. The OptiDry Profile dryer has the same profiling effect as two rows of electric IRs. Web runnability in the dryer is excellent. The energy efficiency was improved by the Valmet Air Dryer Nozzle technology. Moisture profile at the reel was significantly improved (**Figure 24**).

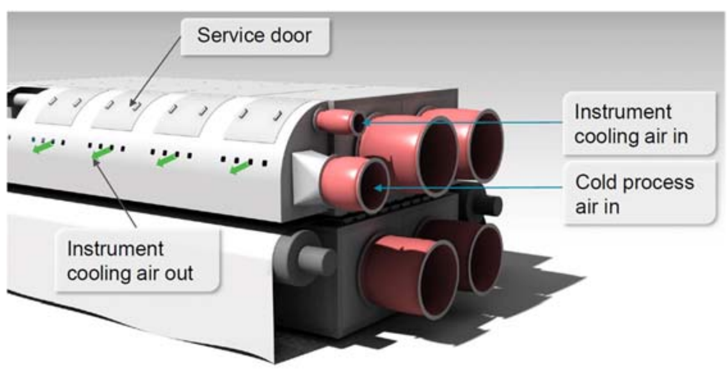

Figure 23. OptiDry Profile uses 300 mm profiling zones and low web temperature.

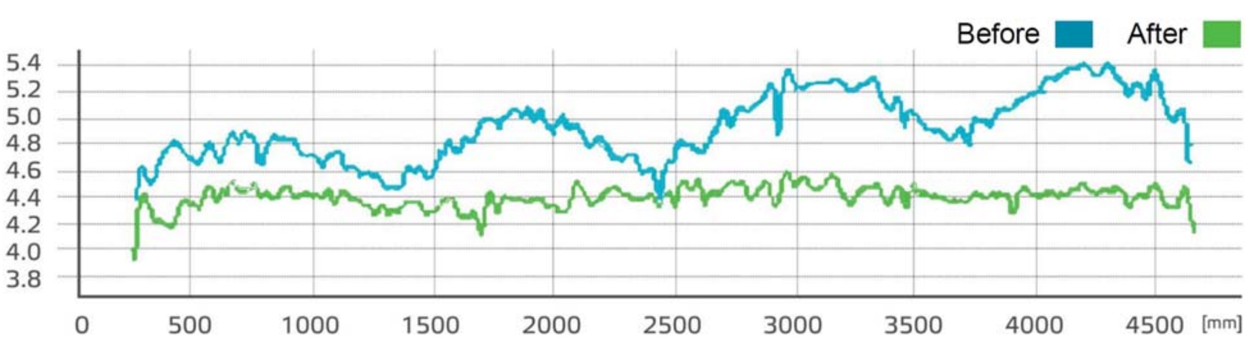

Figure 24. Stora Enso Kemi experienced significantly improved moisture profiles at the reel after the installation of OptiDry Profile on CM1.

OptiDry Chill for effective and contactless web cooling

Figure 25. OptiDry Chill uses a closed concept, eliminating sweating and dripping onto the sheet.

Excessively high paper web temperatures often cause problems when the paper enters the coater. These problems affect the coating process and the quality of the finished product. Valmet's web coolers offer solutions to such problems.

OptiDry Chill (**Figure 25**) is a sheet cooler which, while looking like a hot air dryer, actually uses cool air to float the sheet. It is typically used to cool the sheet before calenders, but can be used elsewhere. In some applications, a sheet cooler is used before the reel to prevent the coating from sticking together.

Figure 26. OptiDry Chill is available in a single- or double-pass layout.

The advantage of using air cooling, instead of cooling cylinders, is that there is no risk of sweating. Some manufacturers use an “open concept” type cooler. The enclosed type supplied by Valmet can operate at lower temperatures than the open concept coolers without sweating and dripping on the sheet.

The main benefits of the Valmet OptiDry Chill web coolers include: optimized runnability, no problems with condensation, effective cooling with proven Valmet Air Dryer Nozzle technology, warm return air exhausted out of machine hall and excellent control of air flows.

OptiDry Chill double pass air cooling units (**Figure 26, left**) are used in the new bulk saving calendering technology, called Aqua cooling calendering. The sizes of the cooling units are very compact and the web passes the units twice. The double-pass cooler with integrated air turn section has a long cooling section with a compact design and an option to add water spray before the entrance for additional cooling.

Summary

The development of new dryer bars and dryer designs have opened up a number of possibilities to improve coater drying with significant benefits in reducing energy, improved finish quality, carbon footprint reduction, increased operating efficiency and improved overall mill profitability. Compared to traditional air drying, savings are in the order of 10 to 15%. Compared to IR drying savings are in the neighborhood of 30 to 50%.

This white paper combines technical information obtained from Valmet personnel and published Valmet articles and papers.

Valmet provides competitive technologies and services to the pulp, energy and paper industries. Valmet's pulp, paper and power professionals specialize in processes, machinery, equipment, services, paper machine clothing and filter fabrics. Our offering and experience cover the entire process life cycle including new production lines, rebuilds and services.

We are committed to moving our customers' performance forward.