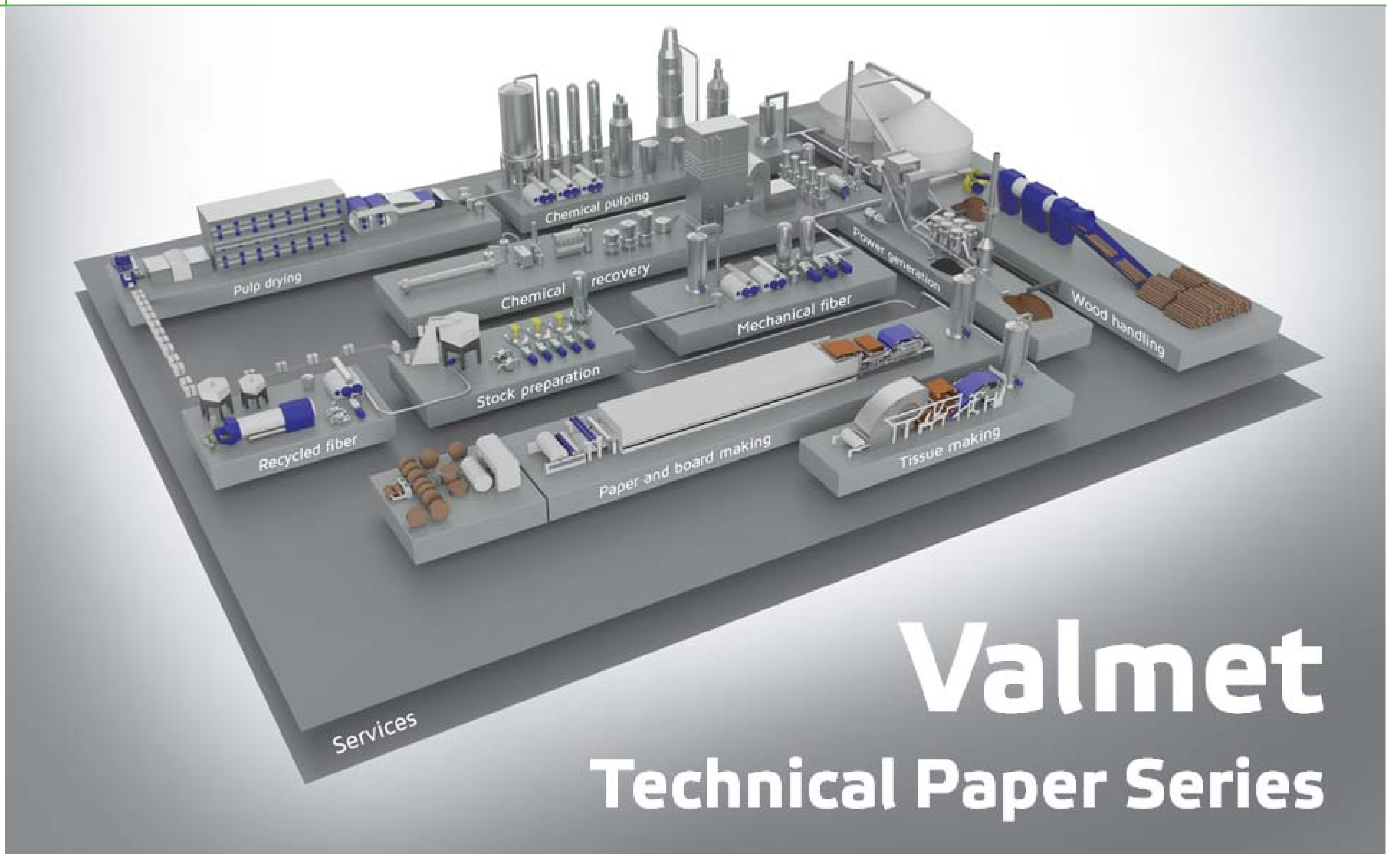

Impingement Drying

Executive Summary

Air dryers using impingement drying have been used to dry coated paper for many years. Valmet introduced impingement air drying technology for printing paper grades as well as for board grades. This technology advancement – OptiDry - remarkably increases drying capacity without adding machine length.

Impingement dryers are usually used at the beginning of the pre- or after dryer section. Due to compact design, the dryer makes an excellent rebuild alternative, with minimal building modifications and short installation time. Steam pressure in the existing dryer cylinders can be increased in the early drying stage. Impingement drying provides a stronger sheet earlier in the dryer section for better runnability. Rapid drying adjustability speeds up grade changes. The final product has more uniform moisture and tension profiles and correspondingly higher quality.

This paper covers impingement drying development, current impingement dryer products and a case study as well as life cycle assessment of suitable OptiDry technology for your mill.

Overview of impingement drying

Impingement drying is a well-established drying technology for drying paper. Air dryers have been widely used to dry coated paper and now Valmet has introduced air drying technology for printing paper grades as well as for board grades. This new technology advancement remarkably increases drying capacity without adding machine length.

The impingement unit is installed typically at the beginning of the pre- or after dryer section. Thanks to its very compact design, it is especially well suited to rebuild applications. It allows optimal space utilization with minimal building modifications, which contributes to a short installation time. It is aligned vertically beneath the dryer group, using space in the basement level. Although the web makes a short journey downstairs, there is no difference to normal paper machine operation, since the operation is automated, including tail threading. It works with all paper grades and can be installed on either a single or a double-felted dryer section, without sacrificing any of the existing dryer capacity. With the added drying capacity, this is a helpful rebuild solution for existing paper machines for overcoming drying capacity limitations. The long impingement drying phase offers enhanced drying capacity and can lead to higher speed and increased production.

Since the dry content of the web increases very rapidly in the impingement area, steam pressure in the existing dryer cylinders can be increased in early drying stage. The fast increase in sheet dry content provides for a stronger sheet earlier in the dryer section thereby giving better runnability. The rapid adjustability of impingement drying power facilitates considerably faster grade changes. These features contribute to uniform moisture and tension profiles and superb end product quality. Furthermore, there is less fiber sticking and the paper has high strain potential. Improved end product quality together with increased production makes this an ideal solution that will improve the machine's profitability.

Developing OptiDry impingement drying for printing paper grades

Impingement drying has been used for many decades for tissue paper and coated paper drying. Energy sources have mainly been electric or natural gas (liquid gas also in some cases). However, impingement drying of printing papers was much slower to come. In the early 1980's there had been some efforts at Norpac, where newsprint was dried using impingement drying. The Papridryer process was introduced in the late 1960's, but only one unit was produced.

Valmet decided to study impingement drying in the beginning of 1990's. In 1993 the first pilot unit was brought on line at the Technical Research Centre of Finland, in Jyväskylä, Finland (**Figure 1**).

Wet reels of paper were made in Valmet's pilot machines and those reels were then dried on the impingement drying pilot machine with different drying parameters. Paper quality was studied with different paper grades and drying efficiency was clarified for all major paper grades. Grammage was varied from 40 to 300 g/m^2 and machine speed from 50 to 1600 m/min in the drying trials. The impingement drying parameters were: impingement air temperature (up to 450 °C) and impingement air velocity (up to 130 m/s).

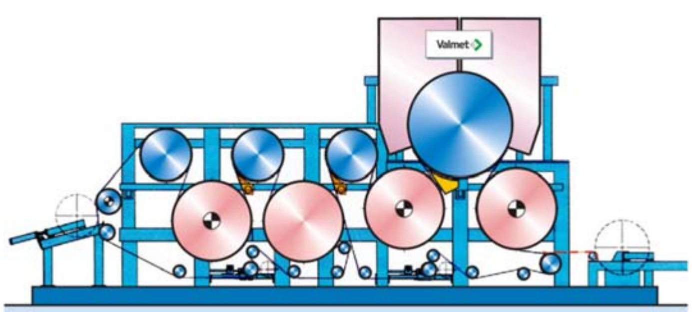

Figure 1. Impingement drying pilot unit in Jyväskylä, Finland (1993).

Conclusions were drawn after extensive research on the pilot machine and it was determined that impingement drying might have a future in printing paper drying. The paper quality did not differ from cylinder dried paper and runnability of the impingement unit was excellent.

In 1995 Valmet's new pilot machine #2 was commissioned having one OptiDry impingement unit in its dryer section (**Figure 2**). Pilot machine #2 is a "total" pilot machine having short circulation, head box, forming section, press section, drying section and a reel.

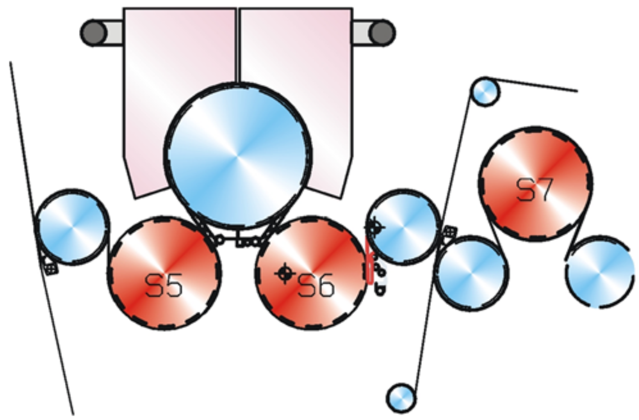

Figure 2. OptiDry impingement drying at Valmet's pilot machine #2 (1995)

This pilot machine was able to run at a speed of 2400 m/min. With this new impingement drying unit the maximum speed was over 2300 m/min with LWC base paper. Impingement drying parameters were: air temperature (up to 430 ºC) and air velocity (up to140 m/s). Trials with the new dryer section proved that both runnability and drying efficiency were at good levels. **Figure 3** represents the evaporation rate achieved in the trials with the impingement unit at pilot #2.

From **Figure 3** it is clear that the drying efficiency by impingement drying was much higher than with cylinder drying. Over 100 kg/(m^{2}h) evaporation rates could be achieved by suitable drying parameters. This proved that applying impingement drying could save space in new machines or increase production rates in rebuilds.

Drying efficiency was excellent and evaporation much higher than with cylinder drying but what happened to paper quality? Numerous trials were performed during subsequent years to study the quality effects of impingement drying. **Table 1 (next page)** shows a summary of one quality comparison of impingement drying vs. cylinder drying.

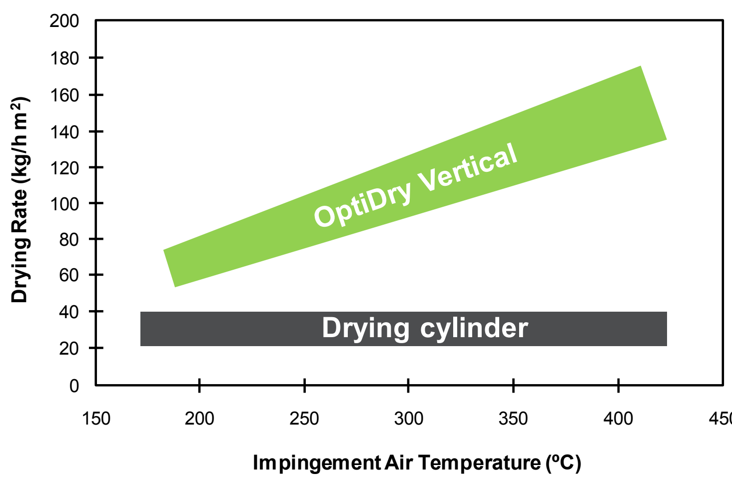

Figure 3. Evaporation rate achieved using OptiDry impingement drying. Pilot machine tests.

From **Table 1** we can conclude that there were no changes in paper quality with fine paper, when impingement drying was used.

Successful installations at two pilot machines led to the first installation on a production machine in 1999. The first impingement drying unit was installed in a machine producing fine papers from 100 to 300 g/m^2. More drying capacity was needed and the machine was rebuilt by adding a shoe press to the press section and an impingement drying unit in the dryer section. **Figure 4 (next page)** presents the layout of this installation.

Date/Time	17:15	17:30	17:45	17:55	18:23	18:45	19:10
Basis weight, g/m^2	78.1	78.6	80.5	80.9	79.2	79.7	80.7
Imping. air temperature °C	136	300	300	0	350	350	0
Imping. air speed m/s	90	90	130	0	130	90	0
Oil absorption, g/m^2 (imp.side)	25.7	25.6	25.6	26.9	26.4	27.3	26.7
Scott bond, J/m^2	235	274	268	233	241	243	214
Brightness, % (impingement side)	83.6	83.5	83.5	83.2	83.4	83.4	83.2
Porosity, ml/min	600	625	575	575	575	625	600
Thickness, µm	112	113	114	117	114	115	111
Density, kg/m^3	689	698	706	693	698	691	725
Bulk, cm^3/g	1.45	1.43	1.42	1.44	1.44	1.45	1.38
Roughness Bendtsen, ml/min (i.s)	929	895	960	946	940	842	873
Tensile strength, kN/m md	3.41	3.61	3.76	3.2	3.29	3.43	3.47
cd	1.29	1.24	1.43	1.46	1.5	1.44	1.63
md/cd	2.65	2.90	2.64	2.15	2.2	2.32	2.09
Tearing strength, mN md	424	438	448	479	464	447	476
cd	563	614	617	538	627	584	607

Table 1. Quality with and without impingement drying. Pilot machine, fine paper 80 g/m².

The first dryer fabric group in the pre-drying section was chosen as the location for the impingement drying unit. This single-felted fabric group, with 13 original steam heated dryer cylinders, was split into two separate groups. The second of the two single-felted groups was converted into impingement drying. This dryer group had four steam heated dryer cylinders and three VacRolls. The impingement drying unit consisted of a 3.6 m diameter vacuum roll, which was grooved and drilled and connected to a vacuum system, and two impingement hoods with integrated gas burners and an air ventilation system.

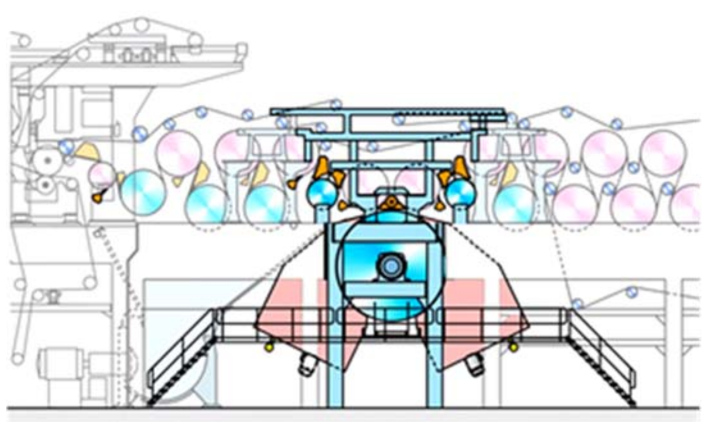

Figure 4. OptiDry impingement drying unit on a production machine (1999)

The goals of the impingement dryer rebuild were achieved, with a production increase at the same paper quality. The corresponding evaporation achieved by the impingement unit was about 120 kg/(m^{2}h). Paper quality changed very little (**Figure 5**).

The figure demonstrates that only the porosity changed (reduced) after the rebuild. No changes in roughness, Scott Bond or other paper properties were discovered.

The conclusions reached from the production machine experience were that OptiDry impingement drying was a good choice for drying printing papers. Hot (even 400 °C blowing air temperatures) had no negative effect on paper quality, and when blowing width control worked properly, fabric life was similar to that achieved with cylinder drying.

OptiDry impingement drying

Effects on coated base paper in a production machine

PAPER MACHINE OPERATING RANGE	
Grammage	90-300 g/m²
Speed	300-930 m/min
Impingement air	350 °C, 90 m/s

Impingement Drying		Off	On
Caliper		100%	100.7%
Porosity		100%	94.8%
Roughness, Bendtsen	Bottom side	100%	101.1%
	Top side	100%	95.8%
Scott Bond		100%	99.6%

Figure 5. Paper quality with impingement drying over long time period in a production environment

However, there were some drawbacks to this installation. There were extensive changes needed to the existing dryer section which resulted in a long shut down. And the large diameter vacuum roll limited the impingement length and was difficult to manufacture and install. As a result the OptiDry concept with a large diameter vacuum roll did not provide papermakers a suitable payback time. This prompted new development work to eliminate these shortcomings.

OptiDry Vertical development

The basis of the new development work was to eliminate the large diameter vacuum roll. Many ideas were studied and finally a simple construction using normal diameter rolls and blow boxes was chosen. This new concept utilized blow boxes and supporting rolls instead of one large diameter vacuum roll. In addition, the unit would be located under the existing dryer section such that minimal or no changes to the existing dryer section would be required.

The new concept looked good on the drawing board, but would it work? How well would the paper follow the fabric? How could tail threading be accomplished? Further pilot machine tests were scheduled to resolve these issues.

The first tests with supporting rolls were made using an arrangement similar to the equipment shown in **Figure 6** at VTT in Jyväskylä.

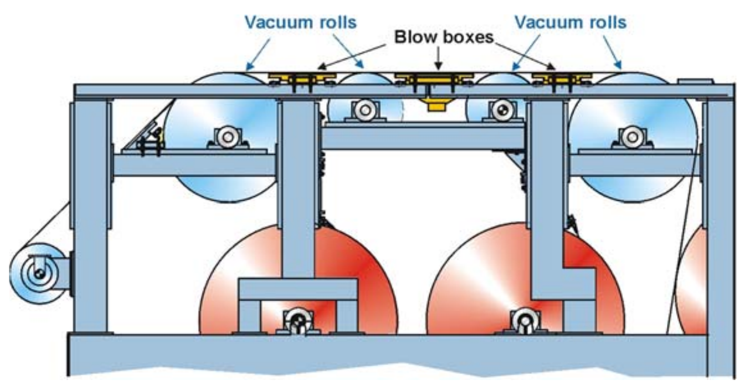

Figure 6. Test equipment at VTT for runnability studies

Tests were made to study the runnability potential of this new concept with dry paper up to a speed of 2200 m/min. Blow box parameters were determined as well as the functioning parameters of vacuum rolls. These tests showed very clearly that paper would adhere to the fabric surface by using suitable underpressure in blow boxes and vacuum rolls.

The first tests proved that runnability could be achieved, but the VTT machine was not set up to test tail threading. Valmet pilot machine #1 in Rautpohja, Finland was chosen to test threading. In 2003, a vertical geometry without impingement hoods was added to pilot machine #1 (**Figure 7**).

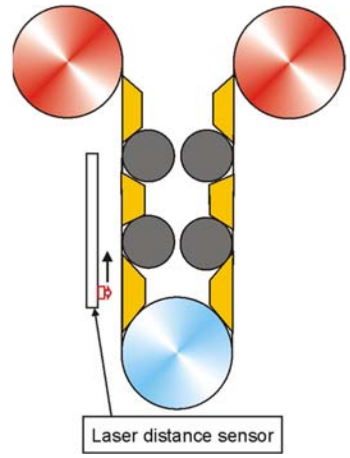

Figure 7. Vertical geometry OptiDry unit on Valmet's pilot machine #1 in Rautpohja, Finland.

Trials with this concept were run at a speed range of 500 to 1500 m/min. Tail threading was accomplished without ropes and worked at all speeds. The fabric deflection was also studied and was found to be linked to underpressure in the blow boxes and static fabric tension. This was an important factor because if the fabric deflects too much, the impingement distance becomes too great and the heat transfer to the web decreases.

Fabric (and web) deflection was measured by a laser distance sensor (**Figure 7**), which very accurately measured the deflection. A measurement beam was installed such that the entire length between the supporting rolls could be measured. **Figure 8** gives us an idea of the deflection of the web between the supporting rolls.

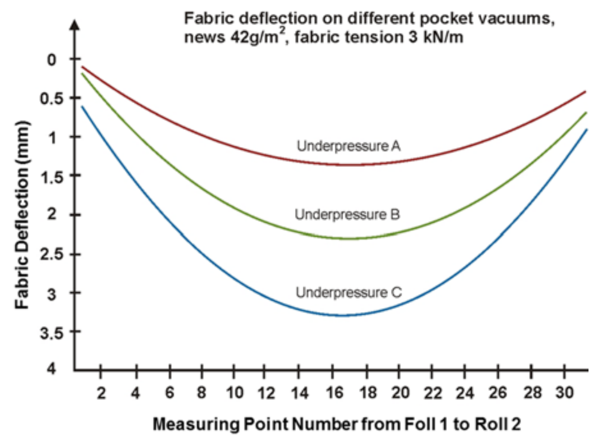

Figure 8. Web and fabric deflection depends on the underpressure in the blow box.

Laser measurements revealed that fabric deflection was quite small when fabric tension was at a normal level and blow box underpressure was suitable for keeping paper on fabric surface. We must realize that in this new impingement drying concept the sheet does not need to be peeled from a smooth surface as is the situation in cylinder drying. That's why extremely small underpressures are enough to hold the paper on the fabric surface. In this trial the maximum deflection was about 3 mm, which corresponded to a small difference in heat transfer (**Figure 9**).

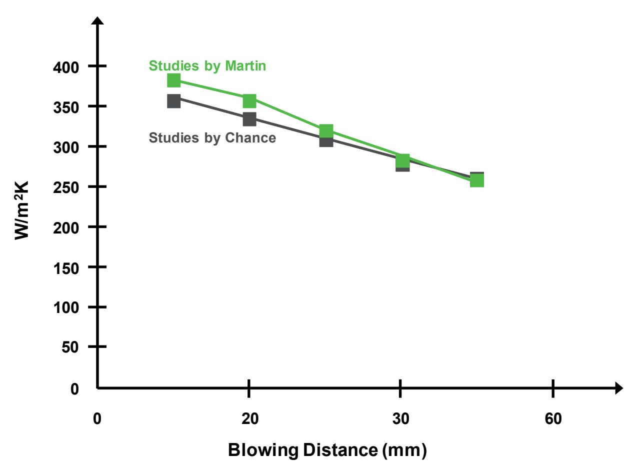

Figure 9. Heat transfer coefficient change as a function of impingement distance.

These trials convinced Valmet R&D staff that paper could be run with this new concept and tail threading would not be a problem. The next logical step was to plan trials at higher speed, as the drive on pilot machine #1 was limited to 1500 m/min.

Vertical drying unit on pilot machine #2

Pilot machine #2 in Rautpohja was capable of running at speeds of up to 2500 m/min. PM2 was reconfigured in August 2004 as shown in **Figure 10**.

Tail threading worked very well and runnability was superior even at the high speeds. When this was proved, the next step was to build drying hoods for this geometry to prove drying efficiency and the effect of impingement air on runnability.

The hoods were added in January 2005. Trials since then showed that the drying worked well, tail threading was acceptable even at highest speeds (over 2000 m/min), and runnability was as good as without the hoods. Drying efficiency was measured by taking paper samples after the impingement unit with and without hoods.

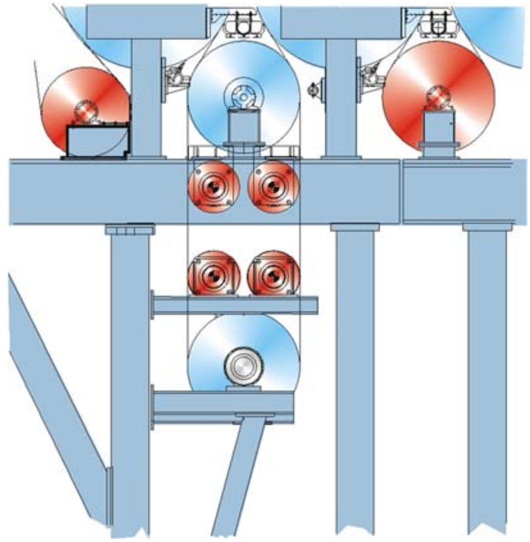

Figure 10. Vertical geometry OptiDry on Valmet pilot machine #2 (2004)

The evaporation rate was at a level of 80 to 130 kg/(m^2h) depending on ingoing web temperature and initial dry content before unit. The dry content in this stage was normally from 48 to 55%, which meant rather constant drying rate at this dryness level. The web temperature before the impingement unit had a large effect on the impingement drying rate. This was due to the fact that with a cold ingoing web a great deal of impingement energy is needed to heat the web before evaporation starts. Data shows that it is beneficial to have a heated web before impingement drying, and when a vertical unit is located in the first or second group of dryers this is the normal situation (steam heated dryers before impingement unit).

OptiDry Vertical impingement drying concept for rebuilds

The new OptiDry Vertical impingement drying concept provides several benefits for rebuilds. It differs from the earlier concept in the sense that it lacks the large diameter vacuum roll supporting the fabric and the web. Instead there are a number of smaller lead rolls on which the fabric and paper web travel. The sheet is held onto the fabric surface by blow boxes located under the fabric. The new concept is suitable for all paper grades and can be installed in different dryer section layouts.

The long impingement drying phase means enhanced drying capacity, higher speed and increased production. Since the dry content increases very rapidly in the impingement area, steam pressure that is higher than normal can be used at an early drying stage. Impingement air velocity adjusts the drying capacity rapidly and speeds up grade changes. The fast dry content increase also means better runnability.

The concept is also suitable for double-tier dryer sections since standard components are used. The rebuild is easy and fast as minimal building and machine frame modifications are needed. An additional benefit is the possibility to use ropeless tail threading as there are blow boxes under the paper web.

The impingement drying unit has a unique air system designed especially for rebuild cases where space limitations are often very critical.

The air system for the OptiDry Vertical impingement drying unit consists of:

- circulation air fans
- gas burners
- supply air line

- exhaust air line
- heat recovery unit.

The new impingement dryer (**Figure 11**) consists of two hoods that blow hot air directly onto the web, with the air heated by gas burners. Air circulation fans as well as gas burners are integrated into the hoods, minimizing the need for outside equipment space. The hood design prevents humid air and heat from escaping into the surrounding air. The two hoods surround the dryer fabric loop that supports the paper web and the dryer fabric is supported by grooved or drilled rolls with blow boxes between them.

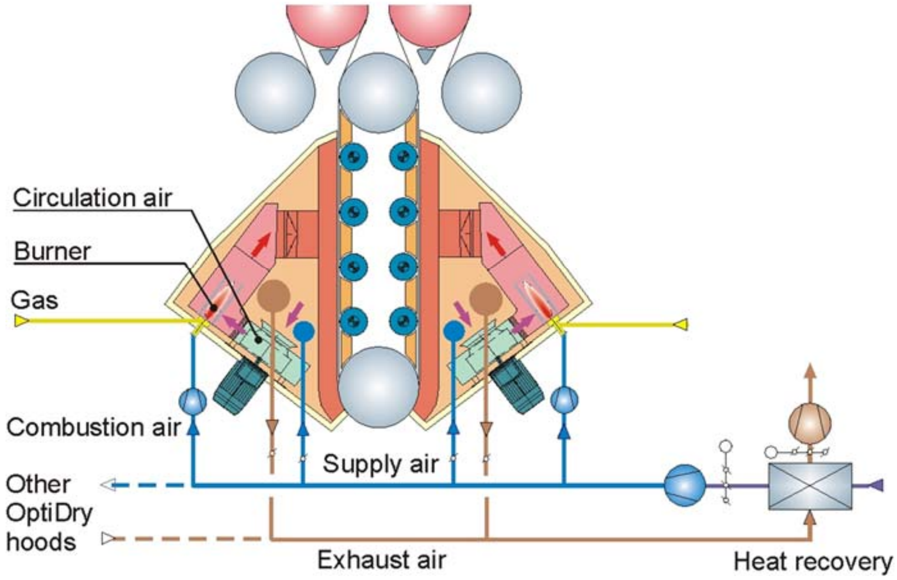

Figure 11. Air system for OptiDry Vertical impingement drying unit

Most of the air is circulated inside the hoods. Moist air is naturally exhausted from the hoods and exhaust air is led through the heat recovery unit, where supply air is heated. No leaks to the surrounding air are allowed and the system is designed such that it works independently from the machine hood. The hoods are well insulated for safety reasons and to minimize heat losses.

The new OptiDry impingement drying concept was refined from the previous version which required a large vacuum roll because of the limitations with the large roll. Big roll manufacturing is quite expensive, installation requires a lot of time and extensive changes to the existing machine are needed, which made the previous concept complicated. Also, the limited drying length on the large vacuum roll was a main item pushing development. The target of the development project was to create an OptiDry concept which was easy to install and gave a short payback time. This target has been achieved with OptiDry Vertical.

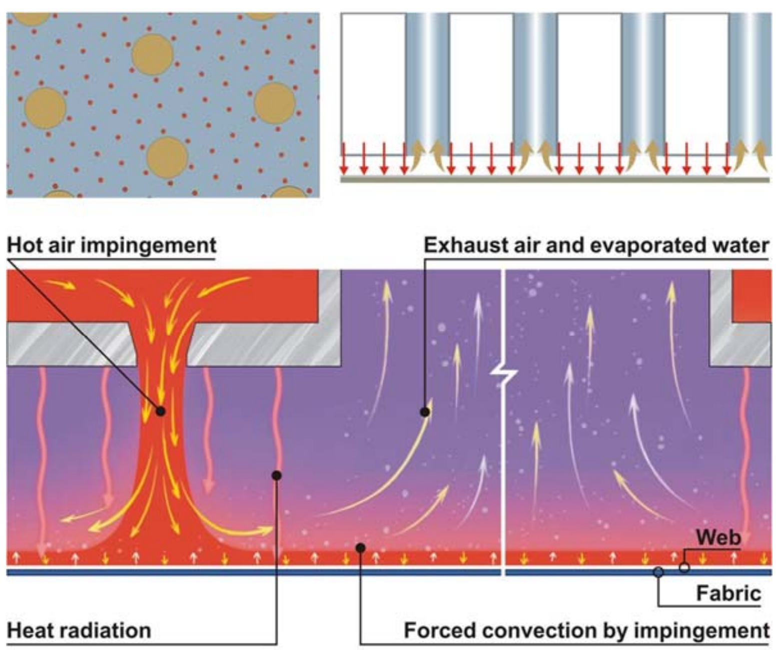

Figure 12. Nozzle plate geometry (top) and drying phenomenon (bottom).

Figure 13 (next page) shows that no changes in existing machine were needed with the vertical unit in a rebuild situation. Provided there is room in the basement, the hoods, rolls and blow boxes can be installed with no changes to the existing machine.

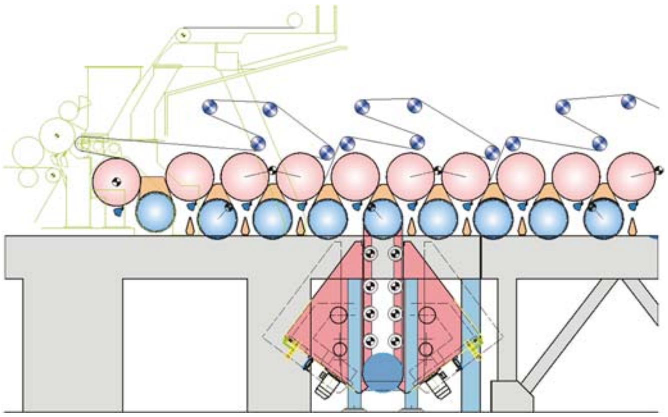

Figure 13. OptiDry Vertical drying concept in a single-felted drying section rebuild

Runnability

Machine speed is the most critical item when runnability components are chosen. At low machine speeds, less than 600 m/min, flat rolls are sufficient. At a moderate speed level, from 600 to 1500 m/min, grooved supporting rolls are needed. Finally, at the highest speeds, over 1500 m/min, vacuum is needed. Air follows the fabric and roll surfaces to the closing nip of the roll and the fabric and over-pressurizes this wedge area. This over-pressure tends to detach the paper from the fabric surface. The vacuum eliminates the over-pressure.

The runnability of the new concept has been tested on pilot machines at machine speeds from 600 m/min to 2400 m/min. Runnability is excellent due to the blow boxes and vacuum rolls. The blow boxes are designed so that paper is held on the fabric surface at every part of the fabric loop. At higher speeds Valmet Dryer Vac Rolls help in eliminating air flows into the closing nip and no over-pressure is built in this area. As a result, the web is firmly held to the fabric.

At the current time, there are three OptiDry solutions for paper and board machines: OptiDry Vertical, OptiDry Curl and OptiDry Twin (**Figure 14**).

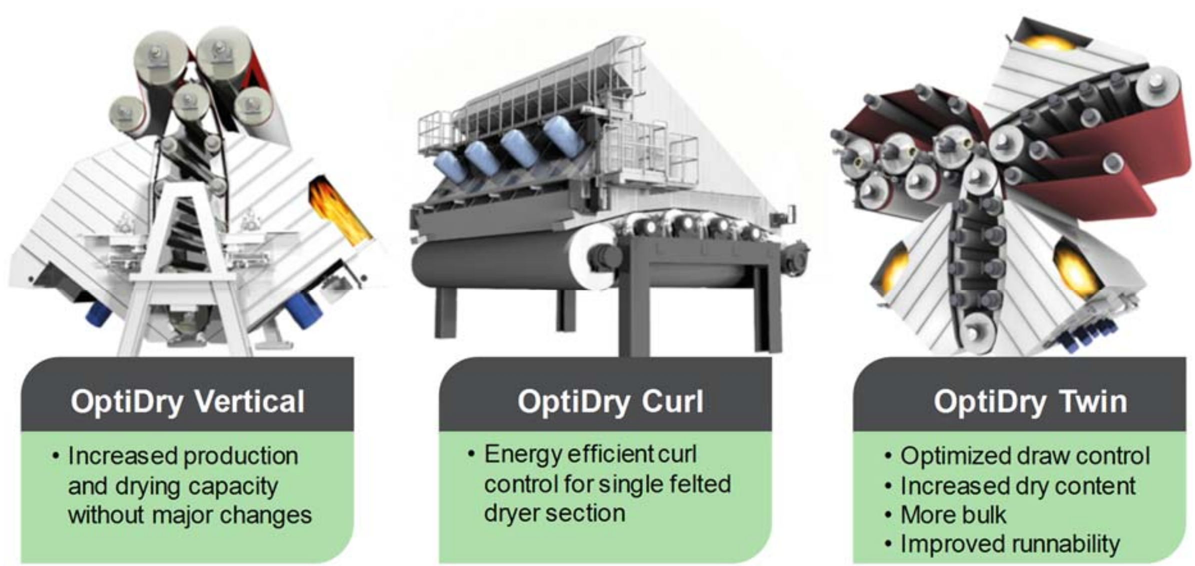

Figure 14. The three OptiDry drying concepts

The OptiDry Vertical configuration has already been described, so attention will now be briefly focused on the remaining two configurations – curl and twin.

OptiDry Curl impingement drying

OptiDry Curl, the new solution for curl control, is based on the impingement drying technology. Traditionally dryer groups with a double-felted configuration have been used for controlling the paper curl by adjusting different top/bottom dryer temperatures and affecting in this way drying on the two sides of the paper. Another traditionally used method is moisturizing (with water or steam), which can also influence the curl of paper.

In the new energy efficient method with OptiDry Curl, the second side of the web is dried last in which case stresses created in the paper are eliminated by relaxation as the dewatering direction changes. The power of impingement drying curl control is so high that it is even possible to change the direction of curl toward the bottom side. Curl control is more effective when more water is evaporated by impingement.

Curl control by OptiDry Curl is suitable for both paper and board grades. No extra cylinders are required, which means a shorter machine hall and every savings.

Figure 15. The OptiDry Curl installed at Propapier PM2 (2010 startup) is used for curl control at the end of the after-dryer section. The steam heated dryer can be changed to gas heated. The circulation air fan and steam coil are located outside the dryer.

The new OptiDry Twin solution

A wet and cold web tends to attach to cylinder surfaces, and speed increases strengthen this phenomenon. As the speed increases, the web dry content tends to drop after the press section. This means that the web is weak and its tension is low. The only way to avoid these detrimental phenomena is to increase the dry content of the web before it arrives at the first steam-heated cylinder. Valmet's answer to this is a new solution called OptiDry Twin.

The OptiDry Twin impingement drying concept has been developed on the basis of the OptiDry Vertical concept and is an excellent solution for the beginning of the dryer section. It has two drying units: a horizontal section and a vertical section. In the horizontal section the paper is heated and dried from the top side before being transferred to the vertical section where drying continues from the bottom side of the web. When the web reaches the first drying cylinder, its dry content has increased by several percentage points. It is very important that the web has a temperature of 70-75 °C at this point. This means that adhesion to the dryer cylinder is not as bad as with a cold web just after the press section.

How much added drying capacity with OptiDry Twin?

The OptiDry Twin dryer has a feature that makes it superior in drying efficiency: both horizontal and vertical sections can be dimensioned to facilitate maximum dry content increase. Roll diameter does not limit impingement length. Space utilization is also excellent in this solution, as can be seen in **Figure 16**.

Figure 16. OptiDry Twin features incredibly efficient space utilization.

Drying efficiency can be estimated by measuring the sheet dry content before and after impingement drying. Pilot machine tests show an average evaporation rate of 90-110 kg/m^2h. This high evaporation rate means that an 8-10 % dry content increase can be obtained on a high-speed newsprint or LWC machine, which, depending on the press configuration, results in a sheet dry content of about 56-60 % at the first cylinder.

Draw management with OptiDry Twin

The OptiDry Twin dryer involves three different draw locations before the first dryer cylinder; whereas an OptiPress (or SymPress) press section + SymRun dryer section has only one transfer point before the first cylinder. One main target in the development of the new solution was unlimited speed draw control. While the increase of draw from the press section is a key tool in conventional cylinder drying, the new solution only needs enough web tension for the web to stay attached to the dryer fabric on its way from supporting roll to supporting roll.

The dryer lacks a smooth and hot cylinder surface where cold paper would attach to the cylinder, which is why it was assumed that the dryer's draw would be moderate. This phenomenon was proven shortly after pilot machine start-up. A test was conducted with fine paper by increasing the speed from 1,450 m/min to 1,800 m/min while optimizing the speed difference at the dryer.

As can be seen in **Figure 17**, the pilot machine speed was 1,450 m/min at the beginning of the test. The total draw at the three draw points of the dryer was 2.4 %. At this draw level the machine speed was increased to 1,800 m/min and the draws were optimized. The result was amazing: total draw was reduced to 1.1 %, the sheet ran continuously to the reel and no wrinkles or edge flipping were seen at the dryer section.

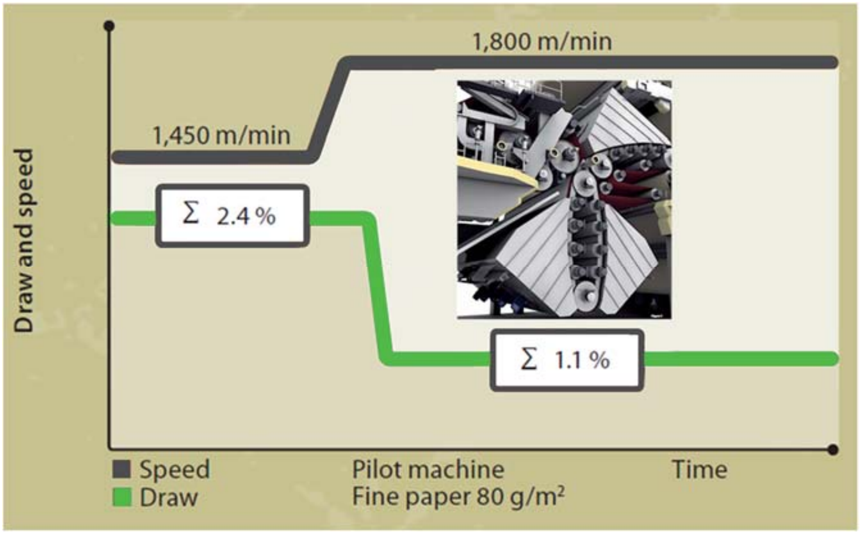

Figure 17. Significant draw reduction with OptiDry Twin on pilot machine

OptiDry Twin as a bulky paper solution

The new dryer represents a good option for producing copy paper at top quality and efficiency. The primary demand on copy paper quality is a good bulk/roughness ratio at the highest possible production speed. This normally means that the sheet dry content after the press section must be as high as possible for good runnability at the beginning of the dryer section.

High press loads are good for paper dry content but not so good for bulk, which will drop at high press loads; if press loads are reduced, runnability will drop and the machine speed would probably be lowered. Increased dry content of the sheet must therefore be achieved by drying, not by pressing, if the highest possible bulk is desired. The answer to this requirement is the OptiDry Twin dryer.

The dryer can increase the dry content after the press section and before the first dryer cylinder of 80 gram copy paper by several percentage points - 5-6 % depending on the drying parameters. The dependence of bulk on press loads can be seen in the pilot trial results in **Figure 18**; a 0.05 increase in bulk means about 2.5 percentage points in dry content. From that we can conclude that the new dryer can offer an excellent increase in both bulk and dry content to ensure excellent runnability.

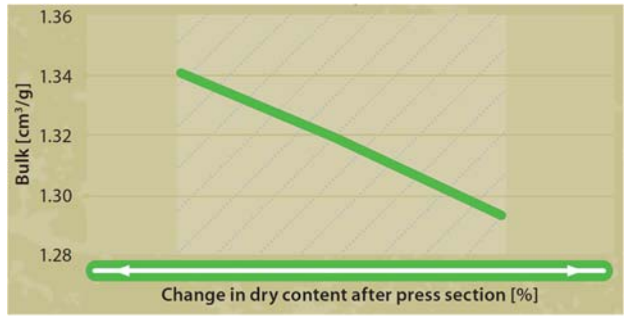

Figure 18. Bulk vs. dry content with OptiDry Twin on pilot machine

A test trial was run to verify the theory. Copy paper was pressed so that the difference in dry content after the press section was about 3 %. This difference was removed using the dryer so that the sheet dry contents were the same at the first dryer cylinder. The sheets were normally reeled, dried and calendered to various roughness levels. The results can be seen in **Figure 19**, which shows that the bulk/roughness ratio can be optimized with OptiDry Twin. Press loading release makes the paper bulky and the new dryer ensures paper runnability at the dryer section by increasing the sheet dry content before it goes to the first dryer cylinder. According to this test, the bulk savings potential of the dryer is huge; in this example the bulk increase is about 0.08 at the chosen roughness level.

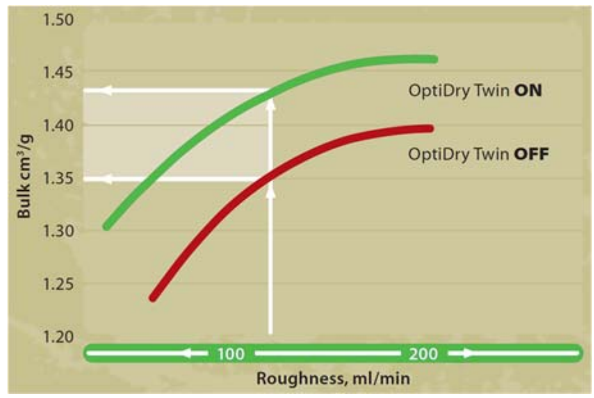

Figure 19. Bulk/Roughness ratio can be optimized with OptiDry Twin.

OptiDry Twin energy requirements

The new solution considerably shortens a new papermaking line; in the case of fine paper the number of cylinders is reduced from 45 to 32. Production, as well as solids content after the press section, is the same for both lines. A shorter paper machine hall means lower investment costs. In addition to that, the higher efficiency of the new concept will shorten the investment payback time.

The total energy use of a line equipped with an OptiDry Twin unit or a conventional dryer section is about the same. However, part of the steam is replaced with gas in the OptiDry Twin concept. The lower level of steam consumption indicates a smaller power plant and a lower investment.

Rebuilding a drying section with OptiDry Twin

Drying capacity is limiting production on a large number of existing paper machines. The impressive drying capacity of the OptiDry Twin dryer will provide a noticeable speed increase, while the length of the machine will remain unchanged.

For example, when an OptiDry Twin unit is installed on a copy paper line running at 1,200 m/min, the speed of the line can be increased to 1,400 m/min. This analysis takes into account a reduction in solids content after the press section by 2 percentage points from 48 % to 46 % due to the speed increase. The total capacity increase achieved with the OptiDry Twin dryer in this case is as high as 16 %.

Total steam consumption remains unchanged in the preceding example. The additional production is dried with gas in the OptiDry Twin unit. This is excellent because the capacity increase will not need any adjustments in the power plant, and there is no need for investment in additional steam production or reduction in power production with a CHP process. Energy use per metric ton will increase with increasing speed due to a reduction in the sheet solids content entering the drying section at a higher speed.

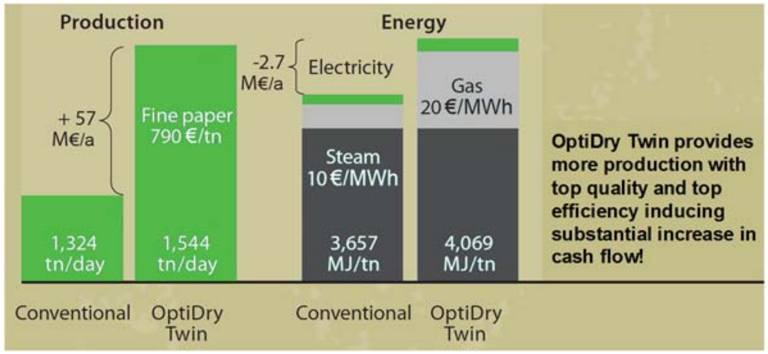

Figure 20. Example of increased production with OptiDry Twin

OptiDry Twin benefits to the papermaker

The OptiDry Twin dryer offers a sophisticated way to increase paper machine efficiency and paper quality on both new and rebuilt machines. Moreover, a substantial capacity increase is gained in rebuilds, as illustrated in **Figure 20**. The production increase is 220 t/day (from 1,324 to 1,544 t/day), based on the data used in the preceding example. Assuming a paper price of EUR 790 per metric ton, the additional incoming cash flow could be as high as EUR 57 million per annum. The capacity increase will raise annual energy costs, which represent only a fraction of total costs, by EUR 2.7 million or less.

Excellent runnability and considerable potential for increased capacity and improved paper quality make the OptiDry Twin dryer a profitable investment for every papermaking line. The dryer is a solution where the dry content of paper is increased just after the press section so that sheet dry content and the temperature of the paper are at a high level at the first dryer cylinder. This prevents sticking, strengthens the web, and enables faster operation than with a conventional dryer.

One main target underlying the development was optimal draw. This target has more than been fulfilled, and in the future papermakers will have access to a new tool for quality and runnability control.

Case Study - Steinbeis PM 4 increases production capacity by 15 % with OptiDry Vertical impingement dryer

The German Steinbeis Papier Gluckstadt GmbH & Co. KG focuses on producing high quality printing papers from 100 % recycled raw material. This traditional company was established in 1911 and the first paper machine was built in 1923. Today the company produces sustainable recycled paper with two paper machines in its Gluckstadt paper mill in Germany. The main market area is Western Europe, but the company has customers who value office paper made of 100 % recycled raw material all around the world.

In spring 2008, the mill needed more production capacity to better meet the needs of its customers and its PM 4 had a limited drying section. The company studied the possibilities of increasing its drying capacity and instead of extending the machine length they decided to invest in Valmet's solution – the OptiDry Vertical impingement drying technology. With this dryer, there was no need for major changes in the dryer section (**Figure 21**). OptiDry Vertical can be installed in an existing dryer section without increasing the

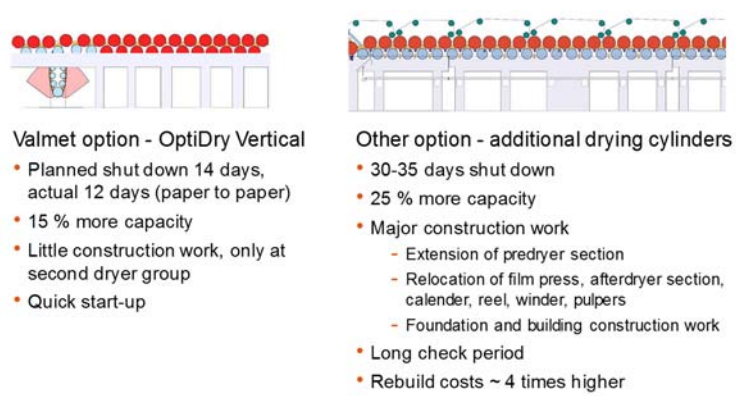

Figure 21. Steinbeis PM4 rebuild options: OptiDry Vertical vs. more cylinders

machine length, and with a minimal rebuild of the current dryer. In many cases this is the most economical way for dryer enhancement – and often the only way.

Why choose Valmet and the OptiDry Vertical impingement dryer?

Dr. Michael Hunold, Production Manager of the Steinbeis mill (**Figure 22**) replies: "Valmet's OptiDry Vertical solution is a very intellectual combination of well proven components, e.g. air dryers, blow boxes and rolls in a new mode. The solution was very attractive due to the drying capacity increase without having to increase the machine length. We also wanted the shutdown to be as short as possible to be able to fulfill our customers' needs. Now I can say the investment decision was the right one."

Figure 22. Dr. Hunold of Steinbeis Papier (right) and Roland Banecki from Valmet (left) stand in front of the OptiDry Vertical dryer.

The rebuild was scheduled for May 2009 with only 14 days' shutdown time - a tight installation schedule. However, the startup took place ahead of schedule on the 12th day and the machine started producing saleable paper right from the first day. The impingement dryer was able to be in continuous use shortly after the start-up. The implementation of OptiDry Vertical was smooth and successful. The guaranteed drying capacity was quickly gained and the new dryer now provides enough drying capacity for a 15 % production increase and about 175 m/min machine speed increase. The paper quality is as good as before the rebuild and the investment has already proven worthwhile.

How did the project, installation start-up and post start-up go?

Dr. Hunold comments: "Installation was well organized. We are very pleased with the fact that the OptiDry Vertical dryer achieved the guaranteed drying capacity so fast and that the start-up was so easy. We made saleable paper right after the start-up. We are very satisfied with Valmet's performance in this project. OptiDry Vertical gives us possibilities to look further to the future. This really was the right solution for us."

Hunold continues: "Our main concerns before the start-up were ropeless tail threading and runnability. And now I must say that the tail threading has been the best thing. There were absolutely no problems and it has worked well right from the first try, and the same goes for runnability. The OptiDry Vertical dryer has successfully fulfilled our needs for capacity increase."

Life cycle assessment (LCA) used to further OptiDry development

Life cycle assessment (LCA) is an environmental management technique whereby the environmental impacts of a product are assessed throughout its entire life cycle, including the manufacturing, use, and end-of-life stages (**Figure 23**). The technique is regulated by ISO standards 14040 and 14044, which impose strict requirements. The assessment consists of four phases: goal and scope, inventory analysis, impact assessment, and interpretation. The ISO standards ensure that reliable, fact-based information is obtained. Although LCAs are generally used to communicate environmental impacts, they can also be used to communicate cost or consumption figures. Life cycle assessment is a valuable tool for

Figure 23. The life cycle of equipment can be described in three steps.

monitoring and calculating the emissions of a product, because of its structured and regulated way of presenting data. It is also useful in guiding thinking towards more sustainable products.

At Valmet, pilot life cycle assessments have been launched Group-wide, with the goal of adding value for customers, so they can monitor and improve their own environmental efficiency. LCAs respond to a growing demand for environmental assessments. Valmet will use the results of these assessments conducted on paper machine lines to consider various possibilities for improving environmental efficiency by, for example, using OptiDry Twin technology.

LCA as it relates to OptiDry impingement drying

In impingement drying, hot air is impinged at high speed against the web to create high drying capacity. The returning air is used to carry out the evaporated water. Installation of an OptiDry Vertical impingement dryer at the beginning of the dryer section not only enhances drying, but can also allow the steam pressures of the cylinders to be increased. The dryer is located in the basement and there is no need to find space for extra drying cylinders and to relocate the dry end equipment. This means less construction work and a shorter shutdown time.

Installation of an effective OptiDry Twin dryer after the press section of a modern paper machine leads to a remarkably shorter drying section, and thus also to a shorter paper machine and shorter machine room – which saves land, construction costs and material. At the same time, it is possible to increase the bulk of the paper, improve runnability, save expensive raw material (pulp) and produce higher-quality paper with higher efficiency than is possible with traditional dryer sections.

In manufacturing, we take building impacts into consideration. A paper/board machine with impingement drying means less land use, less building, less concrete, less steel, etc. A drying section with an OptiDry Twin dryer can be 12 m shorter than a drying section with just cylinder drying, which means some 3,000,000 kg less concrete and 180,000 kg less steel in the building, and approximately the same amount of reduced waste in the end-of-life treatment. Time-of-use is the most significant factor when studying the lifetime environmental impact of a paper machine. When using the machine, energy consumption is the most significant factor increasing the environmental load.

Energy analysis of different drying concepts

Figure 24 shows an energy analysis that was performed to determine the efficiency and benefits of the impingement drying concept compared to normal single-felted cylinder drying in a pre-dryer section. A fine paper machine having a wire width of 5.8 m and a running speed of 1,200 m/min and producing 80 g/m^2 paper is used as the basis for the comparison.

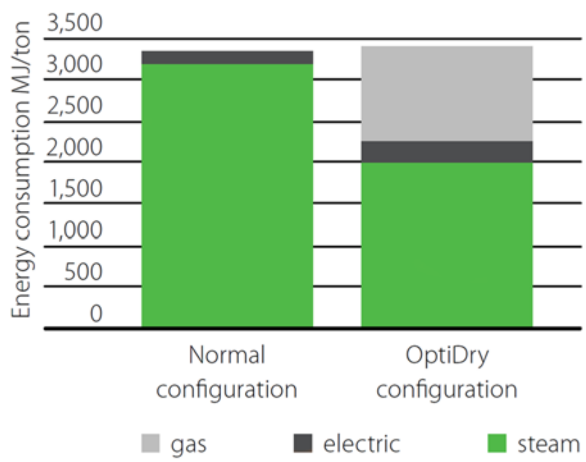

Figure 24. Energy analysis of impingement drying vs. normal single-felted cylinder drying in a pre-dryer section

The energy consumption of the drying section consists of electric and heat energy, which may be steam for the cylinders, or gas for air impingement drying.

The energy consumption in both cases is almost identical. In the case of cylinder drying the total energy consumption is 3,350 MJ/t and consists of electric and steam energy. In the impingement drying process, the amount of steam energy has decreased and been partially replaced by gas, but the total energy consumption stays at the same level, 3,409 MJ/t.

Depending on the steam-generating fuel in the mill's power plant, there is an effect on CO_2 emissions. **Figure 25** shows a comparison of the CO_2 emissions of different drying methods. The steam is generated in a power plant using coal as the fuel.

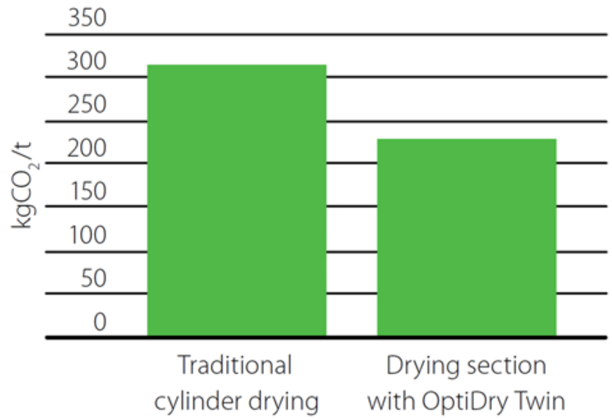

Figure 25. CO_2 emission comparison of traditional vs. OptiDry drying (steam is generated by coal)

The impingement drying concept applied on a new paper machine brings major benefits due to the increase in paper dry content (typically 5-6 drying content units) at the beginning of the dryer section. This solution makes it possible in this case to reduce the number of drying cylinders from 35 to 26 in a new papermaking line (**Figure 26**).

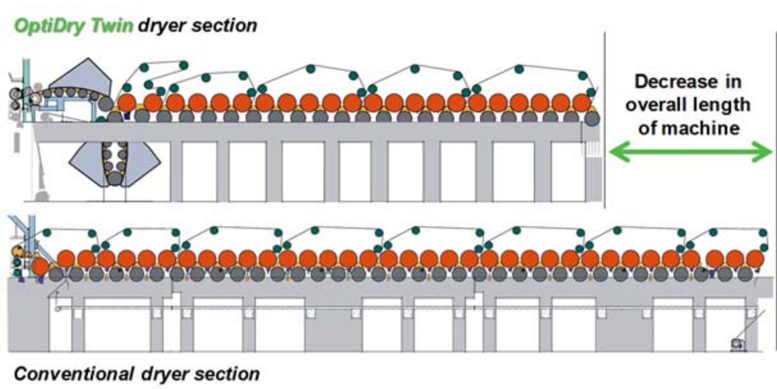

Figure 26. OptiDry concept significantly reduces overall length of a new machine.

Heat recovery from the exhaust air in OptiDry Twin drying is significantly more effective than in cylinder drying due to the higher temperature and humidity of the exhausted air. The heat energy recovered from the exhaust air is about 12.3 MW in the case of the OptiDry concept, compared with about 8.3 MW in the case of a cylinder configuration.

LCA conclusions for OptiDry

The life cycle environmental impact of OptiDry is the same or smaller than that of a traditional drying section. Besides increasing the evaporation rate, impingement drying improves cylinder drying efficiency, paper quality and machine total efficiency, saves resources during construction of the machine and during paper production, and controls the emissions into the atmosphere.

As an embodiment of modern impingement technology, Valmet's OptiDry dryer has been installed in numerous paper and board machines. The benefits mentioned in this article have been proven by the most efficient paper machines using the latest technology around the world.

Summary

A great deal of development has occurred during past years in impingement drying technology. The first OptiDry with a large diameter vacuum roll has been running since 1999 and it has proven that impingement technology is suitable for paper drying. With this installation, Valmet has shown that very hot air can be used for paper drying without detrimental effects on paper quality.

The latest concepts, OptiDry Vertical, OptiDry Twin and OptiDry Curl are further developments beyond the original OptiDry with a large diameter Valmet Dryer Vac Roll. In these new concepts, the large diameter vacuum roll has been replaced with smaller diameter lead rolls with blow boxes between them. The impingement length has increased which has resulted in more drying capacity in one unit and a faster payback time for mills.

The results of tests carried on pilot machines show that runnability of the various OptiDry concepts is excellent. Blow boxes, grooved or drilled supporting rolls and vacuum rolls hold the paper tightly on the fabric surface. High speeds are possible in printing paper grades using ropeless threading. Tail threading can also be accomplished with ropes for slower machines.

Life cycle assessment has driven Valmet's development of OptiDry concepts, and continues to drive total cost of ownership down while improving drying performance and reducing environmental impact.

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.