Executive Summary

The OptiFlo headbox family introduces a new level of performance with a modular construction developed to meet growing productivity and quality requirements of high quality paper and board machines. The latest member of the family is the OptiFlo Fourdrinier headbox. A mix of the proven technology and new ideas are the cornerstones of this new Valmet headbox.

Improved end product quality is achieved through a combination of re-designed turbulence tube geometry and better CD profiling accuracy. The main benefits for paper production are improved paper quality, higher machine productivity and reduction of energy costs. The new OptiFlo Fourdrinier headbox technology also makes new applications available.

An overview and detailed background of the new headbox, as well as mill experiences of headbox application are presented.
OptiFlo Fourdrinier headbox overview

The OptiFlo headbox family (Figure 1) introduces a new level of performance with a modular construction developed to meet growing productivity and quality of high quality paper and board machines. The latest member of the family is the OptiFlo Fourdrinier headbox. A mix of the proven technology and new ideas are the cornerstones of this new Valmet headbox.

The headbox plays a key role in producing high quality paper and board products. Designed to produce perfect visual appearance with good profiles across the entire machine, the OptiFlo Fourdrinier headbox delivers improved paper quality and increased machine productivity. Production and quality targets are reached quicker after start-up with fewer web breaks and less broke; high machine efficiency is achieved for a fast return on investment. The advanced design of OptiFlo makes later upgrades possible to handle changing production needs or new control technology with the minimum disruption in production. The same headbox can ensure optimum utilization even though production or quality targets may change later.

Modular construction

Having supplied some of the world’s fastest and widest paper machines, Valmet knows that strong design is the key to obtaining the most reliable headbox operation. Now, with the modular construction, the best "fit-for-purpose" solution is assured with the right strength of construction, and precision can be matched to narrower machine widths and lower speeds too. This makes OptiFlo the ideal choice for a wide range of grades; easily scalable to individual machine requirements and production targets.

Available with single or two-layer capabilities and suitable for both Fourdrinier and hybrid forming sections, the design is very compact making it ideal for rebuilds as well as new machines. With quick and straightforward installation, an OptiFlo headbox will provide improved reliability with easier maintenance for many years of operation.
Better quality
The secret behind the 30% better CD profiling accuracy is OptiFlo’s ejector type dilution system (Figure 3) and patented CD dilution profiling with edge feed control. Unlike traditional designs, profiling water is delivered to every primary tube. The redesigned hydraulics using accelerating secondary tubes provide better turbulence and floc breaking power and deliver a more uniform and stable headbox jet to the wire. Raw material quality potential is maximized and good formation without streaks or stripes enhances end product properties for perfect visual appearance.

Higher productivity
Increased machine speeds and better runnability are made possible by the excellent web uniformity achieved by the OptiFlo headbox. Quicker tuning at grade change, and more uniform web edges providing a wider reel trim, further maximize production capacity potential. Unplanned downtime is minimized with the easy operation and good cleanliness of the headbox to allow extended operation times and shorter maintenance shutdowns. An example of the possible productivity boost is seen in Figure 4.

Lower lifecycle costs
Considerable energy savings are gained with OptiFlo’s ejector dilution system, more efficient tube design and reduced internal pressure losses. Recirculation is minimized and overflow pumping eliminated. The result is a 50% reduction in energy consumed by headbox losses. Lower operating costs are also achieved with OptiFlo’s simplified maintenance requirements and exceptional component accessibility to make service easier and shutdowns shorter (Figure 6, next page).

The compact headbox is easy to maintain and keep clean. The lifetimes of components are maximized. If damaged all critical components are easy to replace without a large rebuild effort or long shutdown. Maintaining even web quality can also help with overall machine upkeep. For example, calender roll lifetimes can be remarkably extended due to flat base profiles coming from the headbox.

Two OptiFlo Fourdrinier headboxes have started up and several more are on order. OptiFlo Fourdrinier is a strong member of the OptiFlo family, and is used in the most efficient paper and board making lines.
The drivers for headbox development

The growing demand for more economical production of lighter weight grades presents a unique set of challenges for production. In the first place, it requires higher machine speeds. Second, the production of board from lower grade recycled furnish often causes quality problems. Finally, the end product still needs to be strong.

The past twenty years have seen a significant decrease in fluting and linerboard basis weights. To compensate for this, it has been necessary to increase machine speeds proportionately, which is already evident in the higher design speeds of new installations. While basis weights have decreased, the use of recycled fiber as the furnish for containerboard has increased.

Economic pressures require cost reductions and this has led to the use of mixed waste instead of high quality OCC (Figure 7). This, in turn, has increased the ash content of the furnish. High speed, low basis weight, and high ash content is a difficult combination if the target is smooth and efficient production. As the raw material itself does not contribute to runnability, the web has to be as even and defect-free as possible.

In North America, demand for paper and paperboard is expected to decline by 0.8% per year by 2025 [2]. The only
potential for growth is seen in containerboard and tissue grades. Demand for containerboards is expected to grow by 0.5% per year by 2025 [2]. When comparing the consumption growth forecast with asset quality in North America, clear potential is seen to lower operating costs as well as improve quality and efficiency with rebuilds and improvement to current paper and board machinery, (Figure 8).

The remainder of this paper goes into detail about the latest in Valmet headbox development, especially the new OptiFlo Fourdrinier headbox. Mill experiences for Fourdrinier and hybrid forming applications with features that improve paper quality, increase machine productivity, and reduce energy costs will be described.

Despite the decline in overall future demand for paper and board, this new technology can improve mill competitiveness. Grade conversion rebuilds from printing papers, for example, to containerboard also open up new possibilities for papermakers.

**New headbox for fourdrinier and hybrid forming: quality and productivity**

The headbox and forming section are mainly responsible for producing the structure of paper and thus creating the very basis of paper quality. With the latest developments in headbox technology, improved end product quality is achieved through a combination of re-designed turbulence tube geometry and better CD profiling accuracy.

The newly designed turbulence generator tube geometry utilizes the turbulent energy created inside the tube in a new and more efficient manner. The CD profiling accuracy improves by as much as 30% with the new closed-chamber dilution system. Both of these factors contribute to a more uniform jet structure and larger scale profiles.

Turbulence inside the headbox plays an important role in generating uniform paper structure. This is equally true in both the production in the turbulence generator tubes and the dissipation in the slice chamber. On one hand, the scale and intensity of turbulent kinetic energy created in the turbulence generator together with fiber and tube length scales dictate the level of fluidization of the stock.

On the other hand, the design of the headbox i.e. the number of rows and slice chamber length, determines the magnitude of the streamwise rate of strain. The strain is defined as dU1/dx1 and is known to be the dominant term affecting fiber orientation (Olson et al. [3] and Ullmar [4]). The headbox design also determines the residence time, thus defining the residual turbulence level, floc size distribution and
the orientation of fibers in the headbox jet. The effects of various acceleration profiles and turbulence intensity (TI) levels on orientation and flocculation have been studied (Putkiranta et al. [5,6]).

One aspect paper machine manufacturers have to consider is the cost/benefit relationship between the head loss in the headbox and the achievable fluidization and profile advantages. Traditionally, this has resulted in high head losses to cover the challenges created by fluid mechanical or geometrical issues, to maintain sufficient fluidization and to ensure mixing in the dilution system.

The new headbox design is able to produce a high quality jet almost regardless of the head loss, i.e. machine speed or flow rate. The new turbulence tube geometry combines:

- the correct scales of turbulence kinetic energy
- an optimized streamwise rate of strain (i.e. acceleration)
- time scales of the flow in the secondary tube and in the slice channel.

This combination results in a more uniform, streak-free and stable headbox jet to the wire section.

Research has shown that the step height, used to produce turbulent energy to fluidize the stock, is not a sufficient, or even the most important parameter for controlling the fluidization level entering the slice channel. Therefore when developing the optimal headbox process, other parameters need to be taken in account. This is especially true regarding the residence times in the turbulence generator tube and in the slice channel. Also important are the scale, intensity, and dissipation of turbulence.

In traditional designs, the maximum floc size determined by the turbulence generator tube geometry is often reached. This occurs because the residence time exceeds all re-flocculation times and the stock is in a predetermined state regardless of the amount of turbulence kinetic energy supplied at the step. This is due to the very low timescales of the re-flocculation process and the dissipating effect of the fibers. The typical timescale of the re-flocculation process has been studied extensively by Valmet together with research institutes (Karema et al. [7]) and is shown in Figure 9.

However, even a low step height and thus low head loss meets demands when combined with correct tube design after the fluidization. By designing the turbulence generator tube to have an optimal residence time the turbulence kinetic energy created inside the tube can also be utilized in the slice channel to minimize all conventional process challenges (Figure 10, next page). These include intensive re-flocculation together with consistency streakiness and fiber orientation streakiness related to boundary layers in the turbulence generator. Even upstream profile defects related to headbox structures can be diminished by utilizing the new process principles.
Two-layer application for fourdrinier and hybrid forming

The new headbox can also be applied to produce 2-ply products with only one forming section (Figure 11). In two-layer headbox applications it is very important to verify the layer coverage.

To achieve excellent layer coverage, all slice jet turbulence and velocity fluctuations in the direction of the slice jet thickness (the Z-direction) must be eliminated. All hydraulic components of the headbox have been designed to minimize slice jet and board web disturbances, and all possible defects and instabilities will be visible in the quality of the final product. Figure 12 shows a top and back side view of a sample.
with a 40 gsm brown-dyed top layer on linerboard (total basis weight 80 gsm). The top and bottom side layer coverage is excellent [8].

**Dilution profiling system**

Basis weight profiling is done by controlling stock consistency locally with an accurate dilution profiling system. Narrow dilution valve spacing does not directly mean accurate control. A good profiling result also depends strongly on how well profiling water can be kept inside every individual control zone after the injection point. All cross flows inside the headbox spread the profiling water and quickly destroy the profiling accuracy. In a modern dilution headbox this is avoided by minimizing flow channels and cross flows in the design and also injecting the profiling water very close to the jet.

In the latest headbox design the injection is done with a new closed-chamber dilution system near the jet. This system forces the profiling water to stay inside the individual control zone, thus allowing precise CD control action alignment to the exact area – peak or valley – in the profile.

This system can improve profiling accuracy by as much as 30% setting totally new standards for a modern dilution headbox (Figures 13, 14 and 15).

In addition to better end product quality, a modern dilution headbox also provides ways to improve productivity and operation economy of a production line. Good examples of this are increased speed potential and faster grade changes provided by a good profiling system.
CD profiles from the headbox are the foundation for many other downstream quality properties of the production line – such as strengths and formation. A modern dilution headbox produces and maintains high level base paper profiles making the operation of the whole line more predictable. This enables more reliable and faster quality tuning in every section of the machine. In grade changes, especially with machines producing a wide variety of basis weights, significant time and broke can be saved. An example of the production of a North American board machine during one week is presented in Figure 16. The picture demonstrates how a modern dilution headbox can also provide flat profiles in wide range of OD weights.

A modern dilution headbox can also remove bottlenecks and increase operation speed of the production line. For example, a more solid web in open draws withstands stronger forces. The web can run more reliably through the production line at higher speeds without the risk of a sheet break. Or if the existing drying section capacity is limited, more capacity can be gained from the lower drying requirements of the flat profiles. When all the high peaks are reliably profiled away, drying capacity can be optimized based on the average basis weight of the web. Over drying is no longer needed for straight moisture profiles. Steam is saved or saved energy can be used for a speed increase.

Product strengths are improved with solid profiles. This can be explained by the higher uniformity of the web structure portrayed by a more uniform profile. When the variation of the profile is low – especially when the thin valleys are corrected away – the variation of the strength of the end product is minimal across the entire web width (Figure 17). This gives room to downgrade the raw material properties.
or reduce end product weights. Additional savings can be gained with cheaper raw materials and lower fiber consumption.

**Energy saving potential**

Considerable energy savings are achieved through more efficient tube design and reduced internal pressure losses of the turbulence generator and the closed-chamber type of dilution system of the new headbox design. Recirculation is minimized (5%) and overflow pumping is eliminated. The result is a 50% reduction in energy consumed by headbox losses. Lower operating costs are also achieved with simplified maintenance requirements and exceptional component accessibility of the new headbox, making service operations easier and shutdowns shorter. There is no need for a heating system. This also generates energy savings (Figure 18).

**Mill experiences with new headbox**

Figure 19 shows mill experience from a Fourdrinier forming machine in the USA started in May 2012. The machine produces 150-350 g/m² board. The basis weight profile at the reel is excellent after the Valmet rebuild with modern headbox.

The experience of a fine paper machine running 68.2 g/m² offset grade on a modern headbox is seen in Figure 20 (next page). The type of formation is very smooth and soft. There is only a small amount of flocculation in the middle (2-8 mm) and large (8-32) scales. These scales are considered most harmful for printability. The formation and nature of formation are clearly superior.

Whereas recycled fiber based linerboard has traditionally been a 3-ply product in Asia, it is mostly a 1-ply or a 2-ply product in the United States, and a 2-ply product in Europe. The differences are due to the different raw materials and requirements for board properties.

The first production scale new two-layer headbox started up in China in November 2012, and is performing quite well. The machine produces a three-ply product with two forming sections (Figure 21, next page). The concept offers the opportunity to optimize more economical and/or separately treated raw material components in the most efficient way. Also the machine’s wet end operating costs
Flexibility

Forecasting even the near future is challenging. In long term investments there has to be flexibility to adapt to possible changes. To make your headbox investment more secure, OptiFlo Fourdrinier is based on a new modular “Transformer” construction (Figure 22) that enables, with small changes, later upgrades, such as:

- dilution accuracy upgrade,
- later upgrade to online TSO control and
- later production change with dimensioning upgrade.
**Summary**

It is clear that the trend towards lower basis weights will continue. It will require higher machine speeds to reach the targeted production capacity. Economical and ecological board production also requires usage of lower grade recycled furnish as a raw material. Valmet's latest headbox developments for Fourdrinier and hybrid forming applications offer solutions to improve paper quality, increase machine productivity and reduce energy costs.

Hybrid forming with layering technology is a viable alternative technology for the production of lightweight containerboard grades, bringing the speed range up to 1,400 m/min. New two-layer headbox technology is an excellent and compact high-speed alternative to separate-ply multi-Fourdriniers. It offers lower investment costs than gap forming, especially in rebuilds.

**References**


*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.*