Innovative Method for the Production of Structural Elements for the Construction Industry

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ABSTRACT

An innovative method for the manufacture of large decorative ceramic tiles has been developed in Italy by System, Fiorano Modenese. Large, monolithic porcelain gres tiles that can measure up to 3,600 x 1,200 x 3.5 mm can now be manufactured with outstanding mechanical and aspect properties. These huge stone slabs are used as internal and external decorations for skyscrapers, factories, showrooms, hospitals and other residential or commercial buildings.

The innovation consists in reducing by 66% the thickness of the tile maintaining all the good characteristics – impact resistance, flatness, extended variety of surface decorations – in a product which weighs two thirds less than a competing – even if not yet existing in this size – ceramic tile. The robustness of these shatter-proof decorative elements is provided by a mat of glass fiber, glued onto their back using a very thin layer of two-component Polyurethane adhesive.

A dedicated metering, mixing and spraying solution has been designed by Cannon for this sophisticated application. An intense, joined effort has characterised the development phase of this innovative technology, with System and Cannon R&D specialists playing as a team to achieved the desired result.

System's LAMINA® technology is available to all the interested manufacturers and comes complete of the whole production line, from the earths blending system up to the packing and storage area for the finished tiles.

THE CUSTOMER

System S.p.A. (www.system-group.it) is located in Fiorano Modenese, near Modena, the hearth of the Italian ceramic district, and operates in three major areas of activity: Ceramics, Logistics and Electronics. Their founder's experience dates back 35 years, all spent in the constant search for innovative manufacturing solutions, ahead of time. System is today recognized as a leading supplier of automated factories that provide the highest quality standards in the field of ceramics.
The range of available solutions includes equipment and know-how for raw materials blending, pressing, decoration, firing, composite tiles production, cutting, quality control and sorting, packaging and handling.
They quickly extended the initial ceramics technology to logistics and controls, two fundamental components of success in a very competitive, cost-driven field. Internal development of electronic controls and LGV's (Laser Guided Vehicles) provides their technological offer with a further integration of dedicated equipment.

System S.p.A. counts today more than 950 highly skilled persons in their Fiorano headquarters, in a 90,000 m^2 technological campus located at a stone's throw from the world famous Ferrari dream cars factory and testing circuit. The local presence of this prestigious technological leader has stimulated the development of numerous small Companies and technical schools, highly specialized in various areas of mechanics, electronics and engineering services, where the System Group can find skilled personnel and resources for their internal and externally-sourced R&D and manufacturing projects.

The System Group includes 28 local branches in 18 countries, devoted to the distribution and service of their equipment, with three local manufacturing sites in Spain, China and Brasil. The Group employs today a staff of 1,300, with a total turnover of 280 million Euro.

Three of these units – two in Italy and one in Spain – are dedicated to the manufacture of the finished product, the large LAMINA monolithic porcelain gres tiles, that represent the hearth of their current business activity.

THE PRODUCT

System's technological research was not limited to solutions for the manufacture of traditional ceramics: the basic idea of creating a continuous ceramic laminate product generated the LAMINA patent, for the production of the ceramic slabs. The ceramic surface with exclusive dimensions and features matches the quality of the finest ceramic materials and the versatility of laminates in a single product.

System Lamina is a Division of System S.p.A. created in 2001 in Fiorano Modenese with an ambitious target: manufacture the largest, thinnest and lightest ceramic slab ever made.

With LAMINA Clients have access to an agile and effective productive technology, placing on the market products which physical features allow for it to be used in various applications, from the traditional building field to architecture and interior decoration, to infrastructure and photovoltaic panels.

The LAMINA® Process

LAMINA is a highly automated productive process composed by seven main macro functions: deposition of raw material, pressing in press which vary from 15,000 to 26,000 tons, wet or dry decoration, gas/electric hybrid kiln cooking, composite tiles line, dry laser cut of final product and the packaging. The entire process rotates around a special compacting system which turns raw materials, such as clays and feldspars, into slabs. The cooking phase is also innovative: the thermal treatment cycle happens by radiance with an electric unit able to reach 1,250 °C.
The hybrid version, electric/gas fed, further reduces consumption while maintaining the quality features, such as steady shades and stability in the cooling, indispensable to eliminate the material residual stresses. LAMINA also revolutionises logistic systems for traditional ceramics because it deletes the final product storing as cutting and packaging of the slabs happens upon shipment on the basis of the specific order.

The LAMINA® product

LAMINA indicates the assembly of deliverable products which lead to the use of 3.5 mm thick slabs, 1,000 x 3,000 mm or 1,200 x 3,600 mm and specific gravity of only 7 kg/m^2. A 0.5 mm glass fiber layer, duly coupled with this laminate, confers notable resistance and flexibility features.
It is therefore possible to obtain different combinations from this fiber laminate (doubled or tripled laminates with fiber intervals) for applications where the physical features are essential. LAMINA can be applied in the building field for coverings, floors and restructuring, for interior decoration (partition walls, false ceilings, doors and tables) and coverings, for design and for infrastructure (motorway galleries) including the photovoltaic field. *(Picture 1)*

Laminam S.p.A. (www.laminam.it), part of the System Group, produces and sells these types of products in different collections. Their modern factory, a few hundred meters from System's headquarters, covers 16,000 m^2: *(Picture 2)*
The whole production cycle occurs here with a fully-automated concept, completely designed and built by various System Group's companies: raw material's milling and mixing, distribution of powder batches, pressing, trimming of the obtained slabs, decoration with up to 6 colours or three-dimensional patterns, cooking at high temperature, composite production, intermediate storage of the large tiles, laser (or traditional) cutting into the ordered sizes, optical control of final quality, packing and labelling.

Transport of raw and finished products is assured by laser-driven electric LGV's (Laser Guided Vehicles) produced by a sister company, as well as all the electronic controls utilized in the process. The electricity from the grid required for this energy-hungry process is integrated by the in-house production of power, using 9,000 m^2 of PV (photovoltaic) panels installed on the flat factory roof: also these PV panels are manufactured and supplied by a sister company, building them with the same LAMINA concept used for the ceramic decorative tiles.

THE PROBLEM

A ceramic tile, whatever its size, is a hard, strong piece of cooked earth. Being 100% made of compacted natural minerals, with an elevated specific weight, it is rather heavy. The fragile nature of tiles is a fact well known for centuries. Man has replaced primitive low-temperature earth-cooking processes – used for thousands of years to produce pottery and decorative elements – with more sophisticated high-temperature systems; the introduction of high-yield combustibles, electrical kilns, different types of earths and additives has generated porcelain gres, an extremely hard type of ceramic, adapt for heavy duty applications, resistant to all sorts of chemical and aggressive agents. Nevertheless, even a porcelain gres tile features relatively poor impact resistance, and shatters in very sharp, dangerous fragments when hit by a violent impact. One can decide to make a thicker tile to improve impact resistance, but the weight, the raw materials, the energy required to cook it, the efforts made to transport and install it, the waste in case of defects and – final and fundamental – the cost increase with a linear growth.

System was looking for a different solution.

INITIAL DEVELOPMENTS

When System decided in 2001 to concentrate on the manufacture of the largest, lightest and thinnest ceramic slab ever, they realized that the solution to these problems would have been a radical innovation for the conservative world of ceramics: a continuous production process utilizing a non-conventional reinforcement.

Several options were examined and – at the end of a wide selection of materials and processes – a true composite part was conceived, combining the aesthetic and wear resistant properties of a surface layer of porcelain gres with the mechanical strength and assembling capability of a flat layer of glass fiber . This approach – due to the peculiar characteristics of the chosen reinforcement, which is commonly supplied in large rolls of glass tissue, called mat – required a number of dedicated solutions.

The dimensions of the final slab were targeted on a 1,000 x 3,000 x 3.5 mm size, to allow for the use of a single vertical slab when covering the interior of a standard room. Easy to be trimmed to size, the slab would be adapt to lower ceilings. At the same time, featuring a specific gravity of only 7 kg/m2 , it would be light enough to be safely handled even by a single worker. A solution was required to guarantee that such a large and thin element would be free from internal tensions, that would definitely bend somehow the slab and preclude its safe fixing on a flat substrate.

Another solution was required to couple the glass fiber to the slabs: a non-interrupted adhesion between the two elements was perceived as the only way to guarantee a uniform mechanical stress on the back of the slabs. A single air bubble between ceramic and glass mat would represent a potential point of fracture in case of hard, localized impact in that point. A solution was therefore required to guarantee an even distribution of the adhesive and the perfect coupling of each square millimetre of mat and tile.

A third concept involved the logistics of the produced parts: to avoid an expensive and messy storage of finished tiles – complicated in future by an extended range of surface finishes, colours and commercial sizes – it was decided to stick to the principle of "one-size-only" manufacture and use of an intermediate storage for the large slabs. The customer order would have been prepared in smaller sizes – if required – immediately before the shipment, using an automated trimming and sorting line. This would avoid the direct manufacture of a complex mix of colours and sizes.

We will skip here the description of the whole ceramic production line, that will be visible in the videoclip in a few minutes. We will concentrate on that part which pertains to the use of a Polyurethane adhesive as the key element for the manufacture of a perfect thin ceramic slab.

System started evaluating a Polyurethane solution. Contacts and basic lab trials were made with several suppliers of adhesive formulations, and an appropriate one was found, able to guarantee a curing time long enough to allow for the deposition of the glass fiber mat immediately after.

THE CANNON SOLUTION

System contacted Cannon Afros to evaluate the availability of a dedicated machine for this application.

Cannon Afros was at the same time System's supplier of dosing units for Silicone resin processing (used by System to produce their own cast Silicone printing rolls for the decoration of ceramics) and System's customer, having installed four of their automatic warehousing towers for their factory in Caronno Pertusella, near Milano, Italy.

The response was prompt and positive. The specifications were well within those familiar to Afros for their range of machines, and the application was appealing. A preliminary set of trials in Cannon R&D labs would have verified the feasibility of the request, to be further refined with the most appropriate technical adjustments.

The correct application of a thin layer of bi-component adhesive was immediately perceived as the key factor for the success of the composite slab production. Being conceived to work on a continuous line, the technology would have needed all the attentions usually paid on a continuous foaming plant. Due to the characteristics of the formulation, a spray application was defined as the optimal method to evenly distribute the adhesive on the back of the large tiles.

The metering machine had to guarantee a constant component's output in accordance with the speed of the conveyor that moves the ceramic slabs from one station to the next one. Chemical components had to be kept at a very precise temperature, both in the one m3 storage tanks provided by the system supplier and in the metering machine's tanks.

The presence of some mineral filler in the formulation required proper measures to avoid any settling of the charge and any wearing problem to the low-pressure, low-output metering pumps.

The mixing head had to be mounted on a reciprocating mechanical device that allows for the deposition of an even and equal amount of glue on every square centimetre of support. Synchronisation of the Polyurethane's laydown with the movement of the substrate had to consider the fact that a certain amount of material must overlap the layer deposited in the previous pass, but the overlap should not occur on the revolving point of the head's carrier, to avoid undesired build-up of adhesive on the two opposite long sides of the slab.

All these factors considered, Cannon set up in their lab a suitable Cannon B2 low pressure dosing unit connected to a dedicated spray mixing head mounted on a standard robot and organised a first set of trials with System's ceramic slabs and chemicals. The first trials provided soon very promising results. The layer of adhesive was evenly distributed, although a solution had to be designed to avoid a minimum build-up of material at the two extremes of the pouring pattern. The idea of extending the pouring pattern beyond the edges of the tile, to avoid the build up in that zone, had to be scrapped because of an excessive waste of chemicals and of an unacceptable build-up of adhesive in the spraying booth, difficult to remove and to dispose of.

The idea of applying a method widely used in the painting shops – a controlled air-assisted atomization of the liquid formulation, immediately after the mixing chamber –was evaluated. This method required the interruption of the flow of material at the end of each stroke. A very fast control and actuation was demanded, to follow the demanding performance of the head's manipulator.

The existing model of low-pressure, low-output mixing head was fitted with an atomizer specially designed and promptly made for the viscosity and output of the chemical formulation selected by System for their needs. *(Picture 3)*
An extensive testing program submitted the new head to more than 60,000 spraying cycles both with and without chemicals, to prove the industrial usability of the new tool. The design proved to be adapt to the task, and in a subsequent set of lab trials the excessive overspray and relevant build-up of glue were eliminated from the back of the tile. Since the response of the PLC controlling the spraying process was not fast enough to guarantee repetitive results under extreme speed conditions, a dedicate electronic circuit was designed and made in-house, able to provide as quickly as requested the commands to the injectors mounted on the mixing head. This final solution optimised the spraying process, guaranteeing an even application of few grams of a bi-component rigid, compact Polyurethane adhesive on each square meter of ceramic slab.

This achievement allowed Cannon to concentrate on other aspects of the metering phase. The Cannon B2 machine used for the lab trials was originally conceived for the gasketing technology, with all the features designed for the peculiar formulations used in that technology. Since the chemicals required for the ceramic slabs were actually quite different, a dedicated set of special low output gear pumps was identified and installed on the System's equipment. Due to the high client's expectations in terms of constancy of results, a set of mass-flow transducers was installed, able to detect in real time the minimum output variation. Should this occur, a command would be sent in few milliseconds to the electronic inverter driving the speed of the involved component's metering pump, so that an immediate correction of output takes place. The dosing machine operates therefore in a fully closed-loop controlled mode.

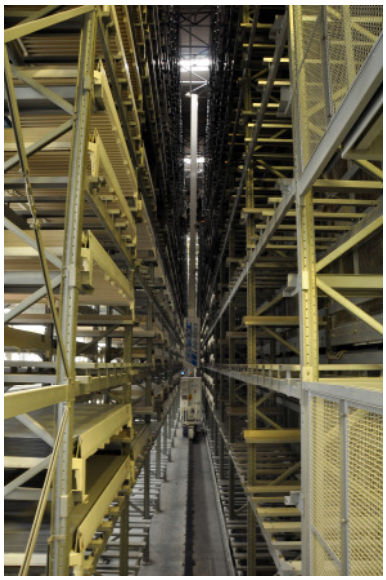
VIDEOCLIP in PRODUCTION at LAMINAM

The video shows the various steps of the production of the ceramic gres slabs at Laminam SpA in Fiorano Modenese, Italy.

Powder blending

The cycle starts from the storage of the raw materials, clay and feldspars of the best quality. Fed to large storage tanks, they are granulated to an optimum powder size and transferred to the blenders.
Here, in accordance with the formulation and colour desired for each batch of slabs, the powders are mixed and homogenized, and transferred to custom-designed dispensers of one m^3 capacity.
These dispensers are brought to a central vertical storage, where they stay until they are needed. *(Picture 4)*

All transports within the factory are automatically performed by numerous in-house designed and made LGV's (Laser Guided Vehicles) that can handle either the powder dispensers or the packs of finished slabs. They are guided by laser heads and reflecting surfaces located in several points of the various halls of the factory. Fitted with sophisticated safety systems, they stop in case of proximity with fixed or moving objects or persons, and are radio-wave controlled by a central logistic management centre.



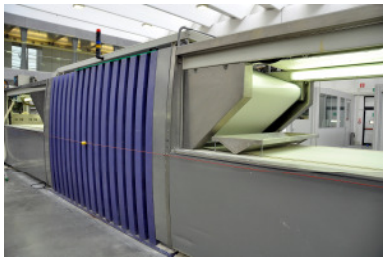
Logistics

These automated warehouses are the alternative to storage on the ground and enable to optimize space.

Two travelling-lifting units place and pick the raw material dispensers on one side of the warehouse and the finished slabs from the other side.
(Picture 5)

The Press System

The production of ceramic gres slabs starts in a dispensing station, where two hoppers, using optimised devices to calibrate the layering, deposit two layers of spray-dried milled earths on the belt of a flexible conveyor: the first and lower layer contains more material providing mass and strength, while the second, upper layer contains the more expensive material needed for the quality surface, the ceramic skin. *(Picture 6)*



The press system is the strength and core of the whole production system. The transformation of the atomised powders in slab is the most delicate, as well as important, step for creating the LAMINA slabs. The slab size is only one, there are no moulds and the whole process has a single stroke, achieved with a special compacter, that represents the evolution and improvement of traditional presses in terms of load, repeatability and, above all, energy consumptions. Pressure of up to 26,000 tons are exerted within this press. A special polymer-made belt presses the material against the surface of the upper belt, supported by a steel plate. When etched, this belt creates the relief on the material surface, with small veins or other surface finishing. *(Picture 7)*

When the compressed slab leaves the press area a rough edge is removed with an automatic trimming system; and the whole surface is cleaned with soft brushes.

Decoration

The wet decoration of the LAMINA slabs is carried out by the proprietary ROTOCOLOR technology: it is possible to use up to six cylinders for decorating these large-sized ceramic tiles, ensuring a steady shade, a better print definition, an high reliability on the product repeatability and fast and simple product changes. The printing matrix is made in house, in another plant nearby, with cast Silicone resins. *(Picture 8)*

Cooking

The cooking process occurs in multi-stage ovens. *(Pictures 9 & 10)*
Cooking in the hybrid kiln FAST FIRE includes three phases:

- The gas pre-heating where, from room temperature, the slab reaches 1,100 °C. With the use of gas this kiln allows to keep very low operating costs.
- The cooking step occurs by electrical heaters, keeping temperature even at 1,220 °C inside the chamber. A fast reply to temperature curves and low thermal inertia create a very high evenness of shades on the product. *(Picture 10)*
- Cooling is carried out by a set of indirect cooling radiators and electric heaters. Cooling is extremely controlled, resulting in a product without residual inner stresses, which are really paramount for these slabs.

As a whole, FAST FIRE ensures top accuracy in the firing curve and high evenness between walls and centre.

At the kiln outlet, the Quallitron Bs equipment carries out a preliminary product quality control.

Composite Production

The entirely automated Composite line is used for applying the glass fiber mat on the slab to improve LAMINA sturdiness, lightness and elasticity.

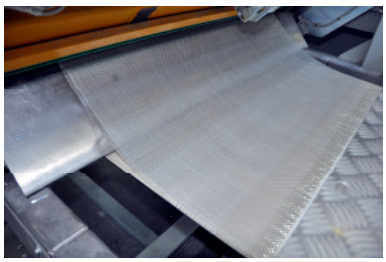
These slabs, as we said before, are reinforced by gluing 0.5 mm of glass fiber bi-dimensional mat, making them more resistant to corrosion, chemical agents, fire, breakage and impacts due to the increasing of elastic module conferred by the additional fiber to the ceramic.

The composite production line includes a first unloading station where slabs are conveyed by the metal platform to the conveyor belt, then wrapped by a protection film in the slab "fair-faced" surface.

The slabs are then passed into an horizontal electric heater to stabilise the temperature (37 °C – 40 °C) of the material to be processed; and finally they are rotated by 180° and centred. With the rough face up, they enter in the spraying cabin. *(Picture 11)*

The slabs are sprayed with a solvent-free, two-component Polyurethane adhesive in a sort of painting booth, provided with a powerful suction hood to remove any mist. The small amount of adhesive that gets sprayed outside the slab is collected and removed from the booth using a disposable paper carpet. Adhesive is evenly applied thanks to a fully automated head carrier, that moves transversally over the slab with a reciprocating path. *(Picture 12 & 13)*

The spray head ensures a perfect mix and deposition of the liquid blend, while the closed loop control system of the Cannon B2 dosing machine keeps all the variables (temperature, viscosity, mixing ratio, recirculation), within the desired working range.

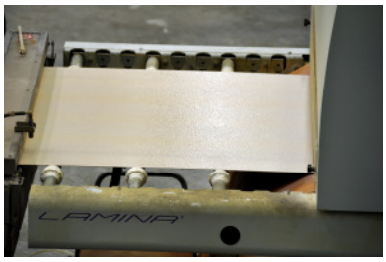


After the application of the adhesive the slabs go to the glass fiber application area, where a precisely cut-to-size piece of bi-directionally oriented glass fiber mat, is simply laid over the rigid support. *(Picture 14)*

The slab is then automatically centred to remove possible offsets. A tooled antropomorphous robot then carries out the squeegeeing operation, to fully wet the glass mat with the still creamy Polyurethane adhesive, to ensure top bonding and to prevent any air spots from being left.

The station is equipped with an automatic tool-change system, so that the operator can change the squeegee without stopping the working cycle. *(Picture 15)*

Then, the curing step to harden the bonding agent is made in a vertical stacker/drier. The product stops here for several minutes, then the protective film is removed and the finished slab is loaded automatically on the unloading tray.



Two types of products can be obtained with this process: *(Picture 16)*

- LAMINA 3+, a 3 mm ceramic slab with a glass fiber structural reinforcement, for a total thickness of 3.5 mm.
- LAMINA 7, a sandwich of 2 Lamina 3+ with an interposed glass fiber mat applied with Polyurethane adhesive. Its physical features allow to pass the car crashing tests recommended for ventilated façades.

A triple laminate is also produced for special heavy-duty applications.

Two complete composite lines are installed side by side in this factory: the simplest features one Cannon dispensing station, while the more complex one features two Cannon stations. These are used in sequence, one after the other, when a double or a triple laminate is produced.
(Picture 17)

A heated double layer press ensures to this products a perfect adhesion on the whole surface of the panel.

A single line can manufacture 70 standard slabs per hour, while the more complex one can produce up to 35 double and triple slabs per hour.

The stacks of finished slabs are brought to the central storage, where they stay parked until they are requested by the order processing software for a customized delivery. When tiles are ordered in sizes smaller than the large 3,000 x 1,000 mm, the slabs are sent to the automatic cutting area.

Dry LASER cut

The slab's cut is performed in two modes: with a dry Freesize LASER method or with a wet cutting system. *(Picture 18)*
The Freesize LASER system innovates the slab cutting process, increasing productivity and reducing wastes. Freesize LASER removes size limits, reduces processing steps and energy consumption: without water the LAMINA product handling is clean and no drying is required, with remarkable advantages for the packing and shipping operations.

The Freesize LASER cut is performed in four steps: *(Picture 19)*

- Side's grinding: used to remove the glass reinforcement loose fibers from the slab's perimeter, it can reach a max. speed of 60 m/minute on a numerically controlled cutting table, with fixed platform and belts for the automatic slab transfer. After the initial grinding operation, an automatic rotator turns the slabs by 180°
- Positioning: the slab is precisely placed on the engraving bench, with the side to be etched facing up.

- Surface engraving: a computer-controlled positioning ensures the highest stability and very reduced oscillations. The engraving is obtained, at a speed of up to 110 m/min, through a high-power laser beam, suitably designed for the ceramic material, with an excellent duration and performance. The beam cuts the whole glass layer, but engraves only part of the gres tile.
- Slab shearing: it is performed along the grinding-engraving lines, to create the desired sizes. Front, bottom and side scraps are eliminated and sent to a disposal case through crushing belts. The slab is aligned and further conveyed, with a wheel system, to the dynamic shearing machine that separates the pieces along their engraving by using separating rollers. At the dynamic shearing machine outlet the pieces are separated by a variable speed motor-driven roller device; duly positioned and centred, the pieces are moved to the conveyor which brings them to the optical quality control station.

When the parts have been optically examined and approved, they move along the factory towards the automatic packing station and to the shipping department.

PRODUCT PERFORMANCES

LAMINA is above all sheer dimension, which thanks to its lightness and easy-to-process nature multiplies its applications offering innovative solutions that meet large surface requirements of the project and design world. LAMINA, 3 m^2 and just 3.5 mm thick, can be used in the building sector to cover indoor and outdoor surfaces, new and existent walls and surfaces, ventilated and curtain walls, insulated walls, partition walls, tunnels and undergrounds; it can also be used in the ship building sector and in the healthcare, hospital and medical sector. Thanks to its lightness and excellent aesthetic quality, LAMINA is the perfect solution to enrich interior design projects and give life to new applications in bathrooms, kitchens, on cupboards, tables, desks and furnishings in general. *(Picture 20)*

LAMINA is the first surface that combines reduced thickness with large format, high resistance to mechanical stress, chemical attacks, scratching, deep abrasion and bending. The advanced technology adopted to produce the slabs makes them easy to clean and sanitise and resistant to frost, fire, mould and UV rays without altering colour, specifications and properties. LAMINA is the first graffiti proof ceramic surface; it is easy to clean and even the strongest paints can be easily removed.

CONCLUSIONS

The project jointly developed by Cannon and System Lamina has generated a Composite laminate characterised by outstanding mechanical and aesthetic properties.

System Lamina welcomes inquiries concerning their turn-key package, that can be licensed worldwide to manufacturers of ceramic gres decorative tiles.

Cannon is proud of having once more cooperated with an innovative Company for the definition of new standards in a competitive field as it is the ceramics one, and will gladly discuss the needs for the application of Polyurethane, Silicone and Epoxy resins in difficult end uses.

Cannon would like to thank System Lamina and Laminam S.p.A. for the cooperation in the preparation of this paper.

BIOGRAPHIES

Max Taverna
Max was born in Buenos Aires, Argentina, in 1949 and has an education background in Industrial Chemistry.
He worked for Upjohn's Polyurethanes Division in Italy and joined Cannon Afros in 1982 as the European Sales Manager.
From 1986 to 2009 he served as Corporate Director of Communications & IT.
Currently retired, Max cooperates with Cannon (www.cannon.com) for editorial and content-related projects.

Andrea Gozzi
Andrea was born in Modena, Italy, in 1974. He has an education background in industrial mechanics and obtained a Master in Business Administration in 2005.
He worked for System Group Spa (www.system-group.it) from 1996 in R&D , focused on the new Lamina project .
Andrea is now the Business line manager for the Lamina plants.