# Sandwich Panels: Innovative Solutions using Vacuum-assisted Foam Injection


Max Taverna
*Cannon Group*
*Via C. Colombo 49*
*20090 Trezzano s/Naviglio*
*(Milano) Italy*

Matteo Benedusi
*Manni*
*Via Campione, 11*
*46030 S. Biagio di Bagnolo S.Vito*
*(Mantova) Italy*

Piero Corradi
*Cannon Afros*
*Via G. Ferraris 65*
*21042 Caronno Pertusella*
*(Varese) Italy*

Luigi Bertucelli
*Dow Italia*
*Via Carpi, 29*
*Correggio*
*(Reggio Emilia).Italy*

Carlo Cardinali
*MISA Sud Refrigerazione*
*Via Monachelle Vecchia, 7*
*00040 Pomezia*
*(Roma) Italy*



**ABSTRACT**

A new method for foaming sandwich insulation panels has been jointly developed by MISA (a large Italian panel manufacturer), Manni (the polymerisation press manufacturer) and Cannon (the foaming machine producer) with the co-operation of Dow Italia (Polyurethane chemicals supplier) Its functioning concept relies on the controlled application of vacuum into the polymerisation cavity of the press. A proper design of the inner press' adjustment mechanisms guarantees easy operations and consistency of results

High productivity has been achieved (more than 300 panels per shift) together with enhanced panel quality, saving in raw materials and labour cost , and last but not least a very clean workplace.

The new process, moreover broadens opportunities for new Polyurethane technology solutions. Blowing agents families with a wider range of boiling point can be used and, very remarkable, polyisocyanurate foam can now be easily processed with the injection technique.


**SANDWICH PANELS PRODUCTION: CURRENT ALTERNATIVES AND NEEDS**

The advantages and disadvantages of the two current manufacturing methods for insulation panels are well known to the industry:

- **Continuous production** offers very high productivity, low labour cost, very homogeneous foam quality. These advantages cost more in initial investment, and demand a very careful planning of the production mix.
- **Discontinuous production** - achieved with various technical solutions - can be afforded with a lower investment, allows for a more flexible production mix, permits to customise the panels with inserts and different types of outer faces; all this is obtained with more manpower, lower output and - sometimes - a lower panel's quality depending on the foam-distribution methods employed.

The research of a proper compromise between investment, flexibility and output has been pursued for long time by many producers (and equipment manufacturers) Main objectives usually include:

- to provide panels with the best possible functional and aesthetic quality
- to achieve the highest possible productivity
- to reduce inventories, being able to produce nearly just-in-time the required lots of panels
- to easily customise the panels with different facings (sheet type and colours), thickness, and type of foam
- to achieve some savings (in foam, scrap rate, labour)
- to comply with the latest environmental and health/safety regulations

The various - and sometimes contradicting - needs have generated a number of technological solutions that meet some of the requirements - and leave space for further improvement for the remaining ones.

## A DIFFERENT APPROACH

The need to achieve higher productivity of customised lots of panels drives rather towards the development of more effective discontinuous process than towards a continuous process

Two conditions must be met to achieve high productivity in discontinuous process: the panel preparation must be completed 100% outside the polymerisation press, and the demoulding time must be shortened as much as possible.

To satisfy the first condition proper mechanics must be put in place. The second problem mostly involves foam reactivity and pressure profile.

### Mechanical Solutions Are Available

Manni, a qualified Italian manufacturer of sandwich panel plants and hydraulic presses, have introduced since many years polymerisation presses equipped with shuttling lower platens. Two lower platens are foreseen for each polymerisation cavity: while one is holding the foamed panel under pressure for the required curing time the other is parked outside the press, where all the preparation and unloading tasks are executed. Therefore with a Manni 1+1 press it is possible to produce panels in one curing cavity while operators are preparing the next ones in the spare platen. With a Manni 2+2 press (equipped with two superimposed polymerisation cavities) two crews of operators can prepare the metal facings on both sides of the press while two sets of panels are being injected and cured.

The system - already in operation in various countries - guarantees high efficiency and flexibility for a wide range of different models of panels. It is an obvious starting point in the process of optimisation of the production of sandwich panels.

### Working with Process and Chemistry

It's well known to the industry that using a closed mould single injection method a certain "overpacking" has to be applied to the foam in the panel in order to obtain an acceptable distribution of density and of mechanical properties along the panel.

That results in a considerable pressure being developed in the foam and if press is opened when the cell gas pressure is still high and foam is not yet well cured the demoulded panel show an unacceptable swelling.

The degree of overpacking is usually optimised panel by panel looking for compromise between homogeneity of foam properties and reasonable demolding times.

The market demands a better method, free form compromise.

### Vacuum can make it

Several discussions on this specific subject had been held already in the past among DOW Italia, Cannon and Manni for the development of a new foaming and curing technology. Their idea was simple, and complex at the same time: help the expansion of foam with a certain degree of vacuum within the polymerisation cavity. This would help the reactive blend to fill more evenly the available space, thus reducing the overpacking and the resulting extra-pressure on the press platens. A faster demoulding would be achieved, as well as a more uniform distribution of foam density.

Smart concept, no doubt about it: on one side previous experiences in other applications (automotive cushion moulding, elastomer casting, placing slabstock foam plants at high altitudes to get advantage of the lower atmospheric pressure) were supporting some of the features behind the feasibility of the concept. On the other side the obstacles, sadly, were also well known: a panel press is a wide-body piece of equipment that requires massive amounts of pressure to stay closed, where huge masses of different metals are heated and are free to move with different linear expansion coefficients. Several metal parts must be moved hundreds of times per shift, in order to lock the panels into their foaming position. Keeping the polymerisation cavities vacuum-tight in real world production is not as easy as it is when the press is still on the drawing board. On top of this the effect of vacuum on a rising foam, where a complex equilibrium of pressures and flows has to be redefined every second for at least a couple of minutes, was not yet a well-explored piece of land. The changing blowing agent's scenario - with the introduction of HFCs ,of flammable hydrocarbons, and of water blown technology - compounded the problem.

Some serious development work was required.

As it is usual in this case, the experience of a manufacturer would have brought to the research the respect of a schedule and the requirements of real-life production.

MISA Sud Refrigerazione, a leading Italian producer of cold storage cells, has built since 1969 a significant experience in the manufacture of sandwich panels.

A Cannon customer since their very early days, MISA has gone all the way through the development of the Polyurethane technology, starting with small low-pressure units on manually operated jigs, ending in the latest years with sophisticated high-pressure metering equipment and automated foaming fixtures.

Looking for a high-productivity system for their new plant in Pomezia, near Rome, MISA accepted - back in 1996 - the working hypothesis proposed by DOW, Cannon and Manni.

## INITIAL DEVELOPMENTS

A joint development project was initiated in 1996, with MISA looking first into a massive re-design of their product. In order to be produced properly under vacuum conditions the panels had to be re-designed, applying a continuous seal on the four sides, which are normally not covered by the steel facings. Insertion of the locking tools - required for a quick installation of the finished panels – also demanded a major re-engineering of the metal devices, that also brought some simplification in the preparation procedures.

Dow Italia was involved for the design of a formulation with easy processing under vacuum and resulting in foam with optimal mechanical properties. As a first step, preliminary to the design of any panel pilot facilities, activities focused on understanding, by use of experimental design with laboratory moulds the influence of vacuum application conditions on foam processing and properties. Two different blowing technologies were studied: HCFC 141b and water blown. Both of them, the former containing a physical blowing agent, the latter without, showed very encouraging results.

Manni and Cannon were required to provide some pilot equipment for the development phase.
A suitable system was defined to apply vacuum to the polymerisation cavity (all the space confined between the press platens and the four side walls, where various sizes of panel can be placed side-by-side) and to maintain it constant during the various operations that characterise this process:

- introduction of the mixing head in one panel's side,
- injection of foam,
- removal and transfer of the head to the next panel,
- polymerisation.

A small-size press was adapted to the new foaming requirements, fitted with vacuum-making pump and circuits, and panel prototyping trials were initiated during 1997 in the Application Development facilities of DOW Italia in Correggio, Italy
A rigid foam formulation blown with HCFC 141b, , was used for this development. The use of high-pressure foaming equipment and the given range of panel sizes demanded a formulation with a cream time of approx. 15-20 seconds and a gel time of 130-140 seconds.
A high level of vacuum (up to 600 mbar ) was applied to the polymerisation cavity in the first trials.
After some minor adjustments the first panels were produced and tested. *(Picture 1)*

Mechanical properties of the foam were quite satisfactory, but several other aspects of the finished panel required a longer development work before full satisfaction was achieved.
Several minor cavities were noticed on the first panel's surface after some days. Analyses confirmed that they were due to an excess of vacuum in the panel, that adapted slowly to the external conditions and slightly collapsed in certain areas. Significant improvements were noticed when the platen's temperature was strictly kept between 37 and 40 °C, lower levels of vacuum were applied, and a constant rate of vacuum was attained in the cavity for the whole cycle time, from injection to demoulding.
The blowing agent molar composition had to be designed in order to achieve the desired cell-gas pressure profile. Graph 1 shows typical foam pressure curve with the vacuum process in comparison with the traditional atmospheric one. Although the final cell pressure in the foam is lower the dimensional stability resulted remarkably improved as a result of the dominant effect played by the better density distribution and better foam isotropicity. Reactivity was found to be important as well. A reaction mixture that remains too long in a liquid phase can loose part of the blowing agent. On the other side reactivity should be slow enough to allow injection time to end few seconds before cream time to avoid foam disomogeneity. Preferably the ratio between injection time /cream time stays between 0.4 and 0.8.

But, probably the most important factor is being able to assure a constant depression value in the cavity for the whole cycle, from injection to demolding. And to achieve it a special venting system has been developed, placing along the sides of the panels regularly spaced pins of a special design to allow the continuous evacuation from the panel cavity, but effective stopping the foam to extrude out.
At the end of a long development work the panel's mechanical, functional and aesthetic performances were judged with extreme satisfaction and the resulting manufacturing process was ready to go into industrial production.

## INDUSTRIAL PRODUCTION

All final modifications were brought into the formulation, a whole series of different panels was designed to accommodate all the required accessories, the press and the dosing machine were defined with all appropriate vacuum circuits and safety equipment for possible use in future of pentane-blown formulations.

The development of the industrial production was carried on at MISA factory, during 1998, using one adapted existing press. In the meantime an order was placed to Cannon and Manni for the supply of the complete plant, that included:

- Two hydraulic Manni presses "2+2 System" with two Polymerisation cavities of 9800x1400 mm each, for a maximum panel thickness of 200 mm. Specific pressure 2 Bars, Clamping Force 2750 kN *(Picture 2)*
- Four shuttling working platens, all individually temperature controlled (max temperature 60°C) and fitted with automatic hydraulic demoulding system on the four sides of each working platen. Max shuttling speed 15 m/min. *(See Picture 3)*
- Four three-axes manipulators for the high pressure injection heads, with encoder-controlled multi-position devices *(Picture 4)*
- The vacuum plant for the MISA Vacuum System
- The complete panel's press enclosure for possible use of flammable blowing agents
- Four handling devices for the metal facings and the finished panels *(Picture 5)*
- The mezzanine to hold the metering machine, placed over the two polymerisation presses
- One Cannon "A-System 100" high-pressure unit, with two Polyols and one Isocyanate metering lines, with individual temperature control of components and automatic re-filling system connected with a central bulk storage *(Picture 6)*
- Four Cannon FPL* mixing heads, with special long plunger to allow for the injection of foam through the vacuum-tight injection holes located on the sides of the shuttling working platens *(Picture 7)*
- Modular rigid piping with pressure accumulators and system of distributor valves, to feed in rapid sequence the components to the four heads
- Computerised control for the presses, the metering unit, the vacuum system and the overhead handling, complete with production planning software, memorisation of the production parameters for a wide range of panel sizes and chemical formulations, and Statistic Process Control for reporting and Quality assurance.

To allow for continuous development of new models and testing of new chemical formulations without perturbing the production, MISA required also a complete pilot plant, *(Picture 8)* composed by:

- One hydraulic Manni press "1+1 System" with two Polymerisation cavities of 3000x1400 mm each, for a maximum panel thickness of 200 mm.
- Two shuttling working platens, individually temperature controlled, fitted with the vacuum system and more sophisticated testing and inspecting devices, to monitor the panel-filling operation from within the panel itself.
- One standard two-component Cannon "A-System 100" high-pressure unit, with one Cannon FPL* mixing head mounted on a simple head holder

The plant was assembled during the first half of 1999, and, after a short fine-tuning of the whole process, went into full-scale production in July of that year.

Ten operators attend the two presses: two on each shuttling working platen (preparing the panels), one feeding metal sheets and removing finished panels in the four loading/ unloading areas, one shift manager in charge of the foaming process and of the supervision.
MISA achieved very soon a production rate of 300 parts per 8-hour shift, with panel sizes ranging from 600x800 mm till 1200x4000 mm in three different thickness: 60, 100 and 130 mm. *(Picture 9)*

Their practical experience has shown that industrial production parameters vary only slightly from the experiences matured during the development phase.
The most significant notes concern the vacuum system: with a well-defined set of chemical parameters the optimum range of vacuum ranges from 150 to 300 mbar, with vacuum values increasing with the increasing thickness of the panels.
It is important to notice that the desired vacuum value must be obtained in the polymerisation cavity before the introduction of the liquid blend. It is of paramount importance to maintain the vacuum value absolutely constant for the whole filling and curing time.

**PRODUCT AND PRODUCTION CHARACTERISTICS**

The manufacture of MVS (MISA Vacuum System) panels is characterised by a very high productivity, thanks to the rational use of shuttling working platens for the preparation and by a very short demoulding time obtained through the vacuum system. Graph 2 shows the demould time of panels produced with the conventional foaming method, compared with MVS.
An average of 30-40% faster demold times has been achieved across the whole range of thickness (With these demould times the panels show a maximum deformation at demoulding of less than one mm, that disappears after a few hours).

MVS panels are characterised by very good mechanical properties: Table 1 shows very uniform distribution of foam densities, enhanced compressive strength and adhesion .
As mentioned before, an initial very low rate of defects was noticed: during the first three months of production less than 0.5% of the panels were repaired or rejected due to defects. A further improvement of the preparation procedures has brought to practically zero the reject rate in the last three months.

Panels are also aesthetically excellent:

- The surface aspect is free from bubbles or marks. When peeling one panel for quality inspection the foam surface adhering to the steel is remarkably uniform, free from stretched areas and air pockets. *(Picture 10)*
- The side edges are fully covered by a protective strip of expanded thermoplastic, which prevents the foam leakage through the inserts of the locking system.
- No wax is used to release the foam from the adjusting tools within the polymerisation cavity. Therefore the panels are absolutely clean, and can be manually handled more safely. *(Pic. 11)*
- The locks are clean and free from any foam.
- The corners are totally free from those small flashes of foam that escape from bent steel sheets.

The absence of foam flashes and extrusions ("mushrooms") in the panels strongly influences the cleanness and the safety of the working area. Under and around the press no foam scrap is visible, the operators walk safely on wax-free, clean floors, the overall impression is more pleasant and efficient, and cleaning and maintenance costs are reduced.

The vacuum system provides an ideal method for getting rid of any vapour emission from the foaming and curing places. All exhausts are concentrated in a single pipe and conveyed outside the plant with a very simple and energy-conscious device.

**A VERSATILE PROCESS FOR PIR FOAMS**

A very remarkable aspect of the vacuum assisted foaming process is that it allows easy processing of Polyisocyanurate foams with the injection technique. That has been demonstrated with polyisocyanurate foam systems using various blowing technologies like HCFC 141b, HFC 365mfc and recently also with a novel water blown formulations. The latter, a $CO_2$ blown Polyisocyanurate is of particular interest to the sandwich panel industry as it t possibly represent an ultimate solution combining the features of long term environmental sustainability and the excellent foam combustibility characteristics.

**ADVANTAGES**

Let's summarise the advantages :

- MVS panels are produced faster than conventional ones: demoulding times are 30-35% shorter. Return on Investment is proportionally shorter.
- The average distribution foam – at equal overall density – is better than in conventional panels:
- Scrap parts – and all relevant disposal or repairing costs - are virtually eliminated.
- Nice and clean quality panels are supplied, with very high mechanical properties and state-of-the-art insulation efficiency. A premium price applies.
- Workers and production environment benefit from a clean process.
- The new process broadens opportunities for new polyurethane technologies. Blowing agents families with a broader range of boiling point can be used and, very remarkable, Polyisocyanurate foam can now be easily processed with injection technique

**CONCLUSIONS**

The success of MISA Vacuum System panels derives from the intrinsic advantages of the system. Nevertheless a great deal of this success derives from several other factors:

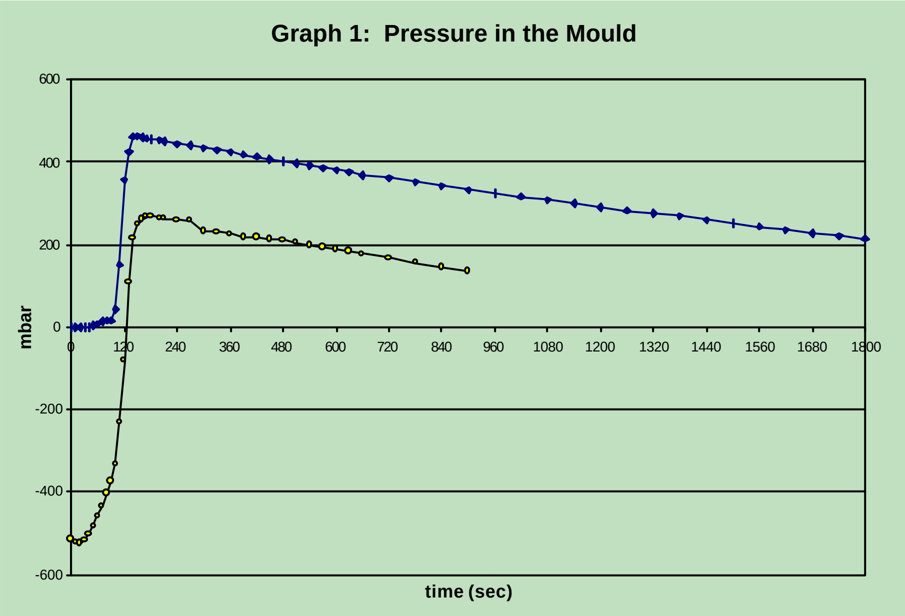
- Dedicated design of the final product, specifically engineered to be produced with this method.
- Maximum care during the whole preparation.
- A specifically designed PU formulation.
- A highly-reliable and easily-controllable foaming and curing equipment

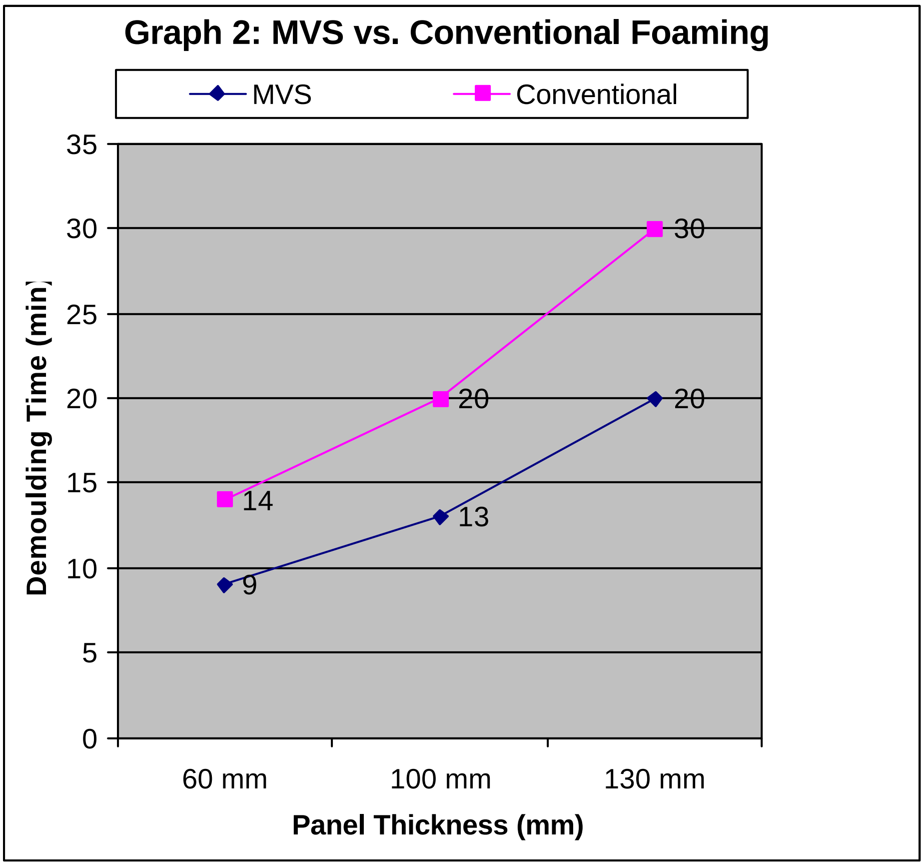
All this spells co-operation and joint development in a tight partnership between customer and suppliers.

Patents - filed in various countries by MISA, Manni and Cannon, either jointly or as individual companies - have covered various aspects of this production system. The network of Cannon offices is available to discuss projects for manufacturing this kind of panels and similar ones in every part of the World.

The Cannon partnership with qualified chemical suppliers and innovative end-users has never stopped giving valuable results!

As we keep saying, Together We Can Make It!



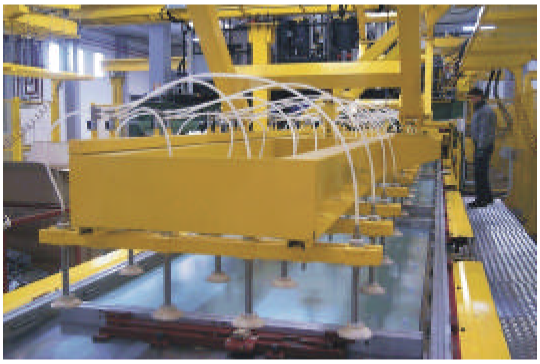

| Table 1 | | Traditional Foaming | | | MVS | | |
|---|---|---|---|---|---|---|---|
| *Test items* | *Unit* | *Typical* | *Min.* | *Max.* | *Typical* | *Min.* | *Max.* |
| Foam Density, Core * | $kg/m^3$ | 37 | 34 | 38 | 37 | 36 | 38 |
| Compressive Strength | kPa | 100-120 | 100 | 140 | 140-160 | 130 | 190 |
| Tensile Bond Strength | kPa | 100-120 | 100 | 130 | 140-160 | 130 | 190 |
| 4 point Shear Strength | $N/mm^2$ | 1.9-2.1 | | | 1.9-2.1 | | |
| Dimensional Stability | | Very good | | | Very good | | |
| Thermal Conductivity | mW/m°K | 22-23 | 21 | 23 | 22-23 | 21 | 24 |
| ** Panels with overall moulded density of 40 kg/m$^3$* | | | | | | | |


*Picture 1 - Initial development with vacuum-assisted moulding gave promising results.*

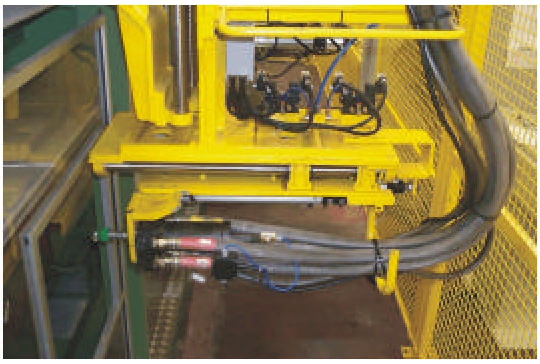

*Picture 2 - Two Manni 2+2 presses*


*Picture 3 -The shuttling working platens*


*Picture 4 - The 3-axes mixhead manipulators*


*Picture 5 - Pneumatic panel handling devices*


*Picture 6 - High pressure metering machines, with two different polyols availability*


*Picture 7 - FPL self-cleaning mixing heads*


*Picture 8 - The complete production unit for research and development*

*Picture 9 - High productivity is achieved in a clean working place*

*Picture 10 - Foam distribution is optimal*

*Picture 11 - High quality panels are obtained*

**BIOGRAPHIES**

**Max Taverna**

Max was born in Buenos Aires, Argentina, in 1949 and has an education background in Industrial Chemistry. He worked five years for Upjohn's Polyurethanes Division in Italy and joined Cannon Afros as the European sales manager in 1982. Since 1986, he has co-ordinated the Group’s communications activities and currently serves as the Director of Communications.

**Piero Corradi**

Piero Corradi obtained his degree in Electromechanical Engineering at the University of Bologna in 1973. As his first job he joined Cannon Afros as responsible of the new R&D laboratory, developing new processing technologies in the field of discontinuous Polyurethane metering and mixing. At Afros Piero has climbed the ladder to the top and currently serves as General Manager since 1994.

**Carlo Cardinali**

After having obtained his degree in Industrial Chemistry at the University of Bologna in 1970, Carlo Cardinali spent his first ten years of career in the Polyurethane R&D field, developing flexible foam applications for the furniture industry. Since 1987 he is a free-lance consultant. He lives in Rome, Italy, where he co-operates with MISA and other Italian foam manufacturers for the industrial development of Polyurethane and other thermosetting resins applications.

**Matteo Benedusi**

Matteo Benedusi is 30 years old and has a 10 years background in insulating panels manufacturing plants. He joined the technical department at Manni in 1989 after having completed his studies as an electronic engineer; his education includes a Master in Business Administration. In 1990 he started to assist the Managing Director in the sales activities and serves now as Sales and Marketing Manager.

**Luigi Bertucelli**

Luigi joined Corradini Poliuretani in 1981, a Systems House in Correggio (Italy) that was then purchased by Dow in 1983. He is currently Techno-Commercial Development Leader for rigid foams for the Dow Polyurethane Systems Houses. He holds a degree in Industrial Chemistry from the University of Parma (Italy, 1978).

© *Cannon Group - 08/04/00*