Innovative Equipment for Automotive Seat Production

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ABSTRACT

Cannon have developed complete systems for the manufacture of moulded polyurethane automotive seating elements made with varying combinations of several raw materials. The resultant cushions – although produced in a random sequence on the same moulding line - are characterised by mechanical properties tailored to the specific application of each part.

This paper describes the components of this technology:

- dedicated multi-component, high-pressure metering machines with closed-loop control of both the output and pour pressures
- dedicated mixing heads capable of processing six components (all with high-pressure recirculation), including low-viscosity TDI-based Isocyanates and water-based additives
- dedicated mould-handling systems for a flexible manufacturing concept based on just-in-time methods

MARKET REQUIREMENTS

A recent analysis of the automotive seat-manufacturing market segment, commissioned by Cannon, to identify the future needs and trends of this group highlighted a number of interesting considerations for a producer of polyurethane processing equipment.

First, the number of suppliers is getting smaller and smaller, due to the extensive merger and acquisition campaign run in recent years by LEAR and JCI. They hold the lion's share of this market, with Bertrand Faure, Trèves, Recticel, Woodbridge, Magna and a number of medium and small local producers holding the remaining shares.

This concentration creates the opportunity for making strategic choices regarding the "make or buy" decision with respect to manufacturing solutions. These large manufacturers have grown significantly thanks to their own successful development of both chemical formulations and moulding plants. Providing them with new machinery sometimes means accepting their request to manufacture a concept that was developed by their own engineering department.

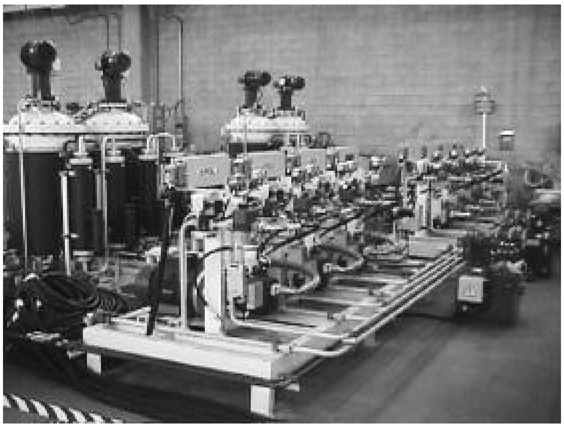
The second aspect concerns the growing demand for simpler, high-efficiency plants, with a reduced number of operators and a high degree of operating flexibility. It must be possible to produce several different parts on the same moulding line so that, in the case of a sudden change in production plans, complete projects can be switched from one production line to another within a very short time frame. This increased flexibility requires careful design of the metering equipment, mixheads and mould carriers because they must be able to perform very different tasks in sequence or by project. A specific request involves the potential to process multi-component formulations, where a wide range of foams can be produced on one machine.

The third aspect, potentially in conflict with the previous concept, involves the development of families of formulations based on specific chemicals: all MDI, MDI/TDI in various percentages, all TDI and special polyols. This means dealing with very different demould times and moulding conditions, that render a generic "seat plant", that was still so useable just a few years ago, obsolete. In this case, specific packages must be available, which conflicts with the concept of high flexibility expressed above.

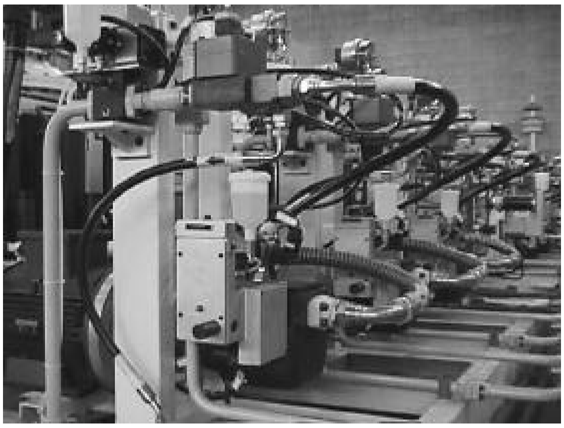
These considerations are behind Cannon's decision to approach the automotive seat market with a series of innovative solutions, specifically developed to meet these requirements.

DEDICATED SOLUTIONS: METERING EQUIPMENT

A high-pressure multi-component metering unit - the Cannon "A-System" Servo - was designed for the automotive seating producers, with a pump-dosing system capable of precisely dosing TDI and other low-viscosity components. Output adjustment on-the-fly and closed-loop control, easy to obtain with piston-driven metering units, was engineered for pump- driven machines as well. The number of main components (polyols and Isocyanates) can be set, as necessary,



Picture 1. The modular design of the "A-System" Servo includes a set of day tanks, a temperature conditioning system, a metering system and appropriate controls.



Picture 2. The output control system on Cannon's "A-System" Servo multi-component metering unit operates continuously.

since the design is modular: each dosing line includes a dedicated tank, its temperature control system, high- and low-pressure filters, recirculation valves, a dosing pump and motor and a portion of the control panel *(Picture 1)*.

Two methods were used to enable fast, precise changing of the output and to ensure closed-loop control of the machine, which is essential to guarantee continuous, accurate output of low-viscosity chemicals:

- via an inverter mounted on the pump motor
- via a programmable step-by-step motor that changes the inclination of the pump swash plate

The output control on the SERVO closed-loop machine operates continuously, comparing the set output value of the inverters with the real output as measured by the volumetric flow transducers. The system enables pouring only when the parameter is within the limits set by the operator via the keyboard and when it is possible to change the pump speed in less than half a second (*Picture 2*).

The SERVO unit also includes maintenance and alarm menus. Through the maintenance menu, it is possible to set limitations on the following parameters:

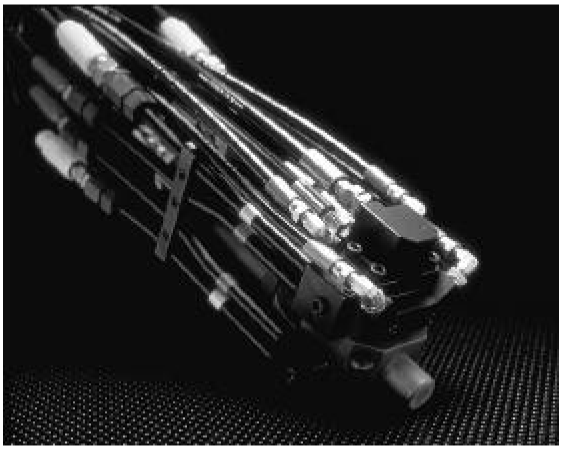
- number of shots
- material consumption
- working hours

Once these set values are reached, the corresponding warning message informs the operator to perform the required maintenance operation.

The programmable stepping device is very precise - the pump can be set at 256 discrete positions - and can be easily programmed through the machine PLC. Since the switching time between formulations can be as low as 0.6 second, multiple ratios can be set within the same pour program to produce multi- hardness and multi-density foams with repetitive results.

DEDICATED SOLUTIONS: MIXING HEADS

Cannon have designed a new head - capable of mixing six components, each with individual recirculation control - to meet the needs of the automotive seat producers who wish to mould TDI-based flexible foams with a maximum of flexibility in their formulation. Several pure ingredients are kept separate up to the point of injection and it is possible to operate each stream on demand, provide high-pressure recirculation and avoid the contamination of components (*Picture 3*).



Picture 3. Cannon's new FPL-AX is capable of mixing six components, each with individual recirculation control.

Though this solution is currently available on the market, competitive mixheads are limited to four streams, their dimension and weight require heavy-duty pour robots while providing speed and pour pattern limitations during operation and they have complex pressure set-up and regulation procedures.

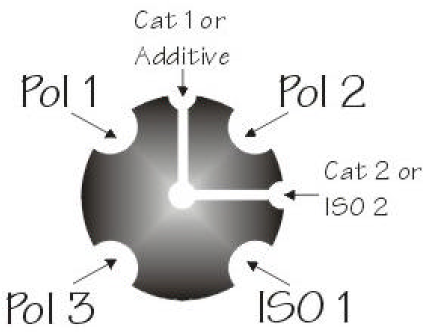
Multi-Component Operation

Four components (Different polyols, additives, flame retardants, MDI, etc) can be fed radially into the mixing chamber and recirculated in high-pressure, in four grooves carved into the closing piston, prior to the foaming. Crossover of low-viscosity components is avoided.

Low-output components (TDI and compatible chemicals, silicon, etc.) are fed axially through two separate holes drilled into the length of the mixing chamber's closing piston. They also recirculate in high pressure, guaranteeing optimum stability of output and pressure at the moment of injection (*Picture 4*). TDI is fed at only 10 bar, with perfect mixing results.

The maximum response time which occurs between two consecutive shots with different formulations is 0.6 seconds.

One of the biggest advantages of this mixing head is its reliability for hundreds of thousands of shots.



Picture 4. The four main components are fed into the mixing head radially while the two lower-volume streams are fed axially.

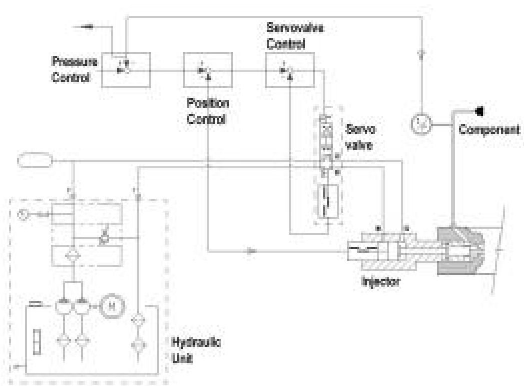
Pour Pressure Control

The pressure control on the component injectors - very important to ensure proper mixing of the different liquid streams - has been achieved via three different approaches:

- closed-loop control of the injection pressure via hydraulic servo valves and feed-back control from the pressure gauges
- open-loop control via hydraulic servo valves
- fixed-position control via various hydraulic valves, pre-set at different values

The package supplied with the head to achieve pressure control (*Picture 5*) includes:

- hydraulically-operated nozzles to be installed on the mixhead for the radial components; each nozzle has a double function:
  - selection of the component to be used in the specified formulation
  - control of the re-circulation/injection pressure during the pour
- hydraulic unit for operation of nozzles
- valves for control of the oil flow; each valve has three positions (off, injection pressure #1 and injection pressure #2)
- high-performance recycle stream distributors with relevant pressure control to maintain non-specified components in high-pressure recirculation, ready to be injected within 0.6 seconds
- one set of high-pressure flexible hoses to connect the proportional valves to the injector nozzles
- appropriate controls



Picture 5. The pour-pressure control system ensures efficient mixing is obtained.

Variable Geometry Mixhead

To ensure proper mixing conditions for a wide range of formulations - which can differ in chemical composition, viscosity, ratio and output - it is important to provide appropriate back-pressure in the mixing area. This can be obtained with the adjustable geometry regulation of the mixing area: the mixhead's larger piston can be mechanically set to partially block the outlet of the mixing chamber when it is fully retracted. This occlusion increases the turbulence in the mixing area, causing more efficient mixing to be obtained.

Advantages

The new multi-component mixhead is characterised by a very compact design: its outside dimensions of 40 x 20 cm and 22 kg weight translate into a high degree of manoeuvrability.

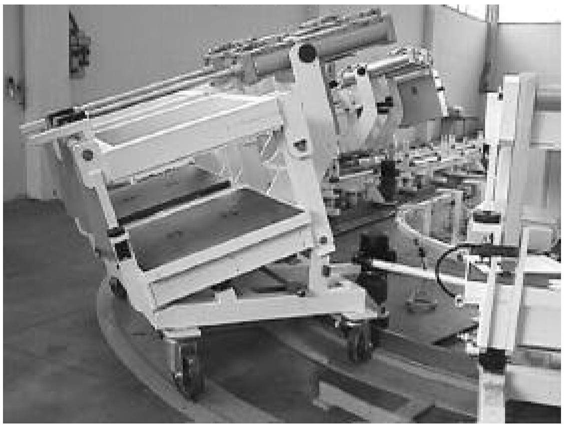
- The pour pattern can be defined very precisely, according to the design of the mould and the position of any inserts.
- The pouring operation can be executed on the open mould without fear of collision with the upper mould half.
- The robot carrying the head can achieve high acceleration and speeds without mechanically stressing the moving elements.

The large number of chemical components that can be handled simultaneously provides a high degree of flexibility in formulations, allowing for optimum use of the moulding line. Several different parts can be produced on the same moulding line and different types of foam can easily be produced in random sequence without forcing the operator(s) to use pre-defined sequences of moulds.

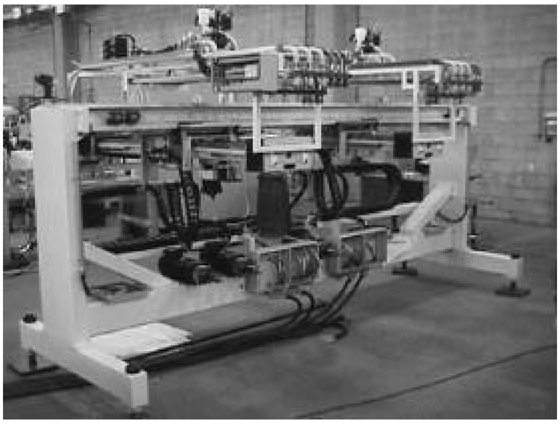
DEDICATED SOLUTIONS: FOAMING ROBOTS

The basic features of a typical Cannon double-arm pour robot, normally supplied to carry two heads (*Picture 6*), are as follows:

- two-axes Cartesian robot with two arms moving independent of each other
- arm movements (along the "X" and "Y" axes) achieved via a rack-and-pinion system driven by electronic variable-speed motors
- racks fitted with position encoders to detect the relevant "X" and "Y" coordinates



Picture 7. The flexible foam moulding system incorporates mould carriers with two independent upper and two independent lower platens to compensate for any difference in mould thickness.



Picture 6. Cannon's double-arm pour robot is typically designed to carry two mixing heads.

The Technical Specifications include:

- max. translation speed for X axis	2.5 m/s
- max. translation speed for Y axis	2.5 m/s
- max. acceleration:	3.5 m/s^2
- max. load on the arm:	120 kg.
- max. "X"-axis stroke:	250 cm
- max. "Y"-axis stroke:	115 cm
- min. distance between the two arms:	55 cm
- available working area:	300 x 115 cm

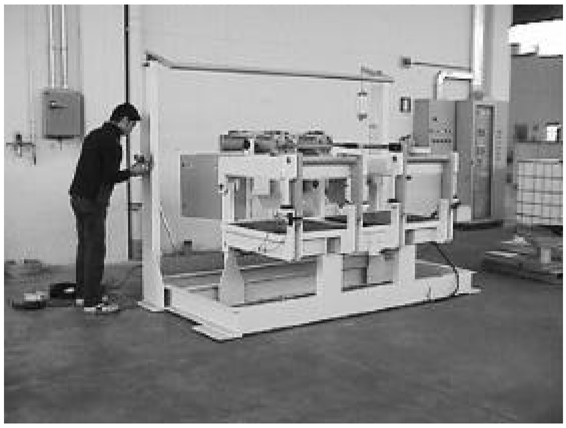
DEDICATED SOLUTIONS: MOULD CARRIERS

The concept of the dedicated flexible foam moulding line relies on a mould carrier having a simple solid structure, with a minimum number of mechanical parts which require maintenance. It consists of two upper and two lower sections linked by means of a hooking system. The presence of two separate lower platens allows the operator to compensate for any difference in mould thickness without incurring any problem by mounting two moulds on the same carrier (*Picture 7*). Insertion, centring and fixation of various moulds within the mould carrier are achieved by means of tensioning screws.

Each mould carrier is usually provided with two pneumatic cylinders for opening and closing. Upon demand, the closing system can be actuated hydraulically or mechanically.

Mould carrier tilting, for optimum evacuation of air during the filling phase, is accomplished with a cam system. Each mould carrier can have two tilting positions: either horizontal or frontally inclined by 20 degrees (*Picture 8*). It is possible to program different angles of opening and tilting to correspond with the type of mould currently being used.

Picture 8. Mould carrier tilting, which ensures optimal evacuation of air during the filling phase, can be actuated hydraulically or mechanically.



Picture 9. Each moulding line incorporates an independent station where service operations can be performed without disturbing the production cycle.

Mould identification – necessary in order to transmit the appropriate mould / formulation information to the dosing system - is achieved with a code reader. The electrical controls for the moulding line are interfaced to the metering system controls in order to co-ordinate all the working processes.

The typical working sequence can be defined as follows:

- **mould identification**: the control system on the moulding line reads the code coming from the field
- **pour program selection**: inside the mixhead manipulator control unit, a schedule - assigning a specific pour program to the different moulds - has to be loaded
- **pour program execution**: the manipulator control unit sends the input to the machine control unit; when the mould under consideration requires dual-hardness foaming, both mixheads are activated, while in the case of a single-hardness seat, only one mixhead is activated

Stroking of the Platens

As stated previously, the lower half of the mould carrier is composed of two independent platens. They are fitted with a guiding system to ensure maximum parallelism between the platens.

In order to ensure equal clamping pressure and complete closure of the moulds over the entire parting line, each platen is stroked by pneumatically inflated tubes. They are inflated after the mould carrier has been closed and deflated just before opening. The total stroke is a few centimetres. The clamping force afforded by this system is 14 tons, using a working pressure for the air bags of three bar.

Mould Temperature Control System

Individual thermoregulator units are foreseen, one for each press. They are mounted on the rear of each mould carrier. This solution affords complete autonomy to each press, making it possible to control the temperature of the moulds prior to being placed on the production line. Subsequently, when a press is placed on the moulding line, it is ready to commence production.

The thermoregulators work in a closed circuit; the relevant refilling has to be performed off-line. The control panel for each thermoregulator is mounted on the operator side for easier access.

Mould Carrier Exchange

The mould carrier concept for fixing and centring is designed for quick mould carrier removal or exchange. The mould carrier can be removed as follows:

- disconnect the electrical plug (positioned on the operator side)
- disconnect the air by removing the relevant joint mounted on the mould carrier
- remove the complete mould carrier (with its thermoregulator) using a fork lift

The estimated time to perform this operation is less than five minutes.

Service Station

A dedicated station where service operations on moulds and mould carriers can be performed, without disturbing the production cycle, is foreseen for each moulding line *(Picture 9)*.

The service station comes with one complete mould carrier on its free-standing frame. It is equipped with a dedicated thermoregulator for warming of moulds destined to be inserted on the moulding line, along with all the required safety fences / light barriers, controls, and connections for air, water and electrical power.

DEDICATED SOLUTIONS: TRANSPORT SYSTEMS

Cannon provides different mould-carrying systems, each customised to meet the customer's needs. The most common solutions are conveyors and turning tables. In the last part of this paper, some innovative concepts which provide a more compact layout, a minimised investment requirement and a maximum degree of flexibility in a changing manufacturing scenario, will be presented.

Oval Conveyor

The conveyor is made of a central steel frame which is positioned on the floor. It is composed of a series of straight-line modules with a curved module at each end and comes complete with a number of carriages running on an oval steel track (also mounted on the floor). On each carriage, mainly composed of a rigid running along a central guide plate, maintain the system on its set path *(Picture 10)*. steel frame positioned on four pivoting wheels, a single lid mould-carrier is mounted. Four idle wheels,

Continuous movement is achieved by means of one drive system being placed between every two carriages. Each driving system has two entrainment wheels running along the guide plate. The entrainment wheels – operated via an AC motor – are maintained in traction along the guide plate by a spring. An inverter is used to adjust the speed from 13 to a maximum 30 ft/min., while the AC motor is fitted with a brake so, in case of an emergency, the plant can stop within a few centimetres of travel.

This system can easily be expanded to incorporate any new business obtained for that range of moulded products. Carousel extensions are achieved by fitting an even number of new carriers to the line and extending the supporting frame accordingly.

INNOVATION

Mould Carrying Systems: FlexiDrum

Developed in the early '80s by Cannon as a revolutionary tool for the production of foamed refrigerator doors, the well-known concept of the rotary polymerisation system is now being proposed as a compact and simple mould-carrying system for the production of automotive seats *(Picture 11)*.

Picture 10. The idle wheels running along the central guide plate maintain the mould carrier on its path.

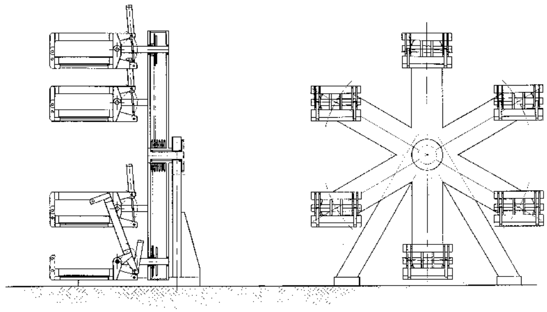
Six or more mould carriers can be fixed on the surfaces of a wheel that rotates vertically – similar to a Ferris wheel, rather than horizontally, as with a merry-go-round. The opening and closing movements can be hydraulic or pneumatic. Mould conditioning can be accomplished using a rotating collector that feeds each mould carrier with water at the desired temperature. Manual service operations are performed on the lower mould half in the first station. Foaming is achieved in the subsequent station using a platform-mounted robot. Polymerisation takes place in the remaining four (or more) elevated stations as they are passed through a compact suction hood that removes the escaping fumes.

Several advantages can be highlighted for this new version of mould carrying system:

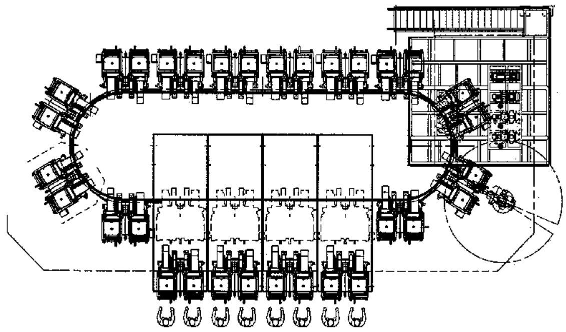
- simplified mechanical construction that does not incorporate wheels which roll along the floor picking up and transporting scrap foam and/or dirt
- optimised layout which will work even when space is limited
- reduced power cost thanks to its vertical layout which minimises the suction area, requiring only one fan for extraction of the fumes
- limited number of operators required

Carousel for In-Situ Foaming

A number of dedicated moulding lines have been designed for the production of in-situ moulded foams. In-situ moulding technology adds a delicate operation to the list of conventional operations (mould cleaning, release agent spraying, insert positioning, foaming and demoulding) that must be executed to mould a standard foamed item: the manual positioning of the textile container into which the foam will be dispensed. This is a delicate operation that requires some time, yet should not penalise the cycle.



Picture 11. The FlexiDrum rotary polymerization system is a compact solution for the production of automotive seats.



Picture 11. The In-Situ Foaming Carousel provides a row of service positions where time-intensive manual operations can be performed without penalising the efficiency of the moulding line.

A practical solution consists of a carousel line with a row of service positions where the operators can work on moulds that have been temporarily taken off-line *(Picture 12)*. When the press leaves the curing area, it passes in front of the first free operator and is automatically disengaged by the dragging system. The moulds can be serviced, taking all the time required, then, when the textile inserts have been positioned, the carrier can be re-inserted in the first available position in the line.

Multi-Hardness and Multi-Density Foams with Natural Carbon Dioxide

The availability of multi-component mixheads with variable geometry opens the path to another interesting option: the addition of natural carbon dioxide for expansion of the foam with an environmentally-friendly blowing agent and reduction of the foam density by as much as 20-25%.

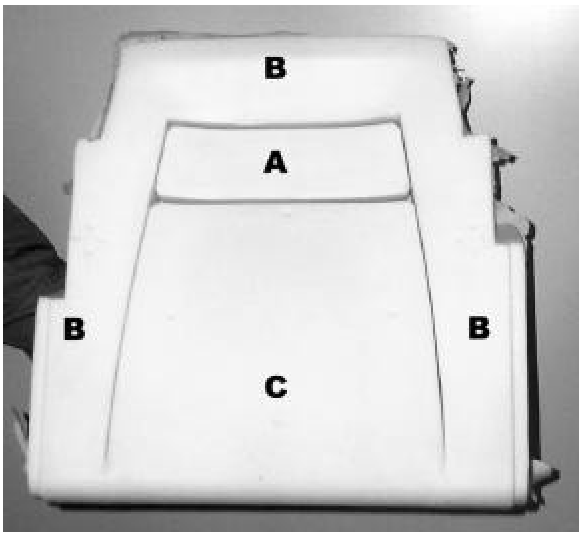
With this new mixhead, it is possible to use two different approaches to add natural carbon dioxide to the formulations:

- CannOxide™ - a technology developed by Cannon to meter natural carbon dioxide at the point of injection, at the desired percentage, into one of the polyol streams
- EasyFroth™ for CO2 – a technology which allows the premixing of given percentages of blowing agent in one of the two components, usually the isocyanate.

Both methods are currently in industrial production, each having operating and investment pro's and con's that must be evaluated according to the production volumes and flexibility required. For example, a car seat with three different hardnesses can be produced using two different formulations for the hard and soft parts - areas "A" and "B" in the photograph *(Picture 13)* - and incorporate some natural carbon dioxide to decrease the seat density below the thighs - area "C".

CONCLUSIONS

Cannon have always invested significant resources into the development of dedicated solutions for the automotive field and have devoted one of its Groups to this specific market. Co-operation with major foam producers and raw material suppliers has generated a number of dedicated technologies that allow a continuing stream of innovative polyurethane products to be used in this leading sector of the industry. Cannon offices and manufacturing plants are available world-wide to supply more information and technological support where needed.



Picture 12. Using natural carbon dioxide for expansion of the foam with Cannon's multi-component mixing head enables a seat with three different hardnesses to be produced.

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 coordinated the Group's communications activities and currently serves as the Director of Communications.

Massimo Castiglioni

Massimo was born in Tradate, Italy, in 1960 and graduated in Electronics in 1987 at Politecnico of Milano with a degree thesis on "Neurons Self-learning Systems".

He worked two years for Bull and joined Cannon Afros in 1989 as Area Manager.

Since 1995 he is the Seating Marketing Manager, and from last year he is responsible of the Cannon Seating and Steering Wheel International Business Team